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EFFECT OF AUDITORY FLUTTER ON THE VISUAL CRITICAL FLICKER FREQUENCY[1]

JOHN C. OGILVIE[2]
University of Toronto

SHERRINGTON devised his experiments on binocular flicker to investigate whether there was a central mechanism governing the integration of neural impulses from different sense organs in a way comparable to the correlation of motor reflexes about a final common path. He stated the proposition as follows:

> Were there to exist such a common mechanism situate as a unit at conjunction of the two convergent systems and were phases of excitement timed so as to arrive from one retina as exactly to fill pauses between excitations transmitted from the other, then there should be evidence of this in the time-relations of the phenomena induced. [12, p. 376]

By stimulating each eye separately with flicker sources of identical frequency, which could be either in or 180° out of phase, he hoped to show that there was a difference between the binocular critical flicker frequencies (CFFs) measured under the two phase conditions.

Sherrington's results led him to conclude that his hypothesis of binocular interaction was untenable, but it has since been shown by Baker (1, 2, 3) and Ireland (7) that this conclusion was in error. Binocular CFF measured when the sources are in phase is in fact higher than when they are out of phase.

Sherrington, for reasons of simplicity, had limited his experiments to a single sense modality. To test whether his proposition might be applied to more than one modality, the present experiment was designed to investigate the effect on binocular CFF of intermittent auditory stimulation, in and out of phase with the visual flicker.

Random noise was considered preferable to a pure tone for the auditory stimulus, since interruption of a pure tone introduces contaminating side frequencies which depend on the frequency of interruption. Random

[1]This paper is based on a thesis submitted in partial fulfilment of the requirements for the doctor's degree in the Department of Psychology, University of Toronto. The research was supported by a grant from the National Research Council of Canada. The author wishes to express his gratitude to Professor E. A. Bott for his helpful interest and guidance and to Dr. D. B. DeLury for his advice on the experimental design.

[2]Now at the Defence Research Medical Laboratories, Toronto.

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noise remains essentially unchanged by interruption since it is already a mixture of frequencies.

Interrupted random noise has been investigated by Miller and Taylor (10) who have treated it as the analogue of visual flicker and named it auditory flutter. The auditory CFF, like the visual CFF, varies with intensity of noise, but the temporal discrimination of the ear is much superior to that of the eye. The noise intensities and frequencies of interruption in the present experiment were such that fusion of the auditory flutter did not occur.

Since it has been shown by Kravkov (8) that visual CFF may be changed by continuous auditory stimulation, measurements of CFF with and without stimulation by continuous random noise were included.

In the present experiment answers to four questions were sought:

1. Will stimulation by auditory flutter in phase with a flickering visual stimulus produce a higher binocular CFF than out-of-phase auditory flutter?

2. Will stimulation by continuous noise change binocular CFF?

3. Is the effect of continuous random noise on CFF equivalent to the effect of interrupted random noise?

4. If the answers to any of the earlier questions are affirmative, are the effects a function of brightness or of intensity of noise?

Method

Apparatus

The apparatus used was based on a design given by Fritze and Simonson (6). It consisted of a square-wave generator which drove a glow modulator tube. The glow modulator, when maximum current is passing through it, emits a mixed white light, having a continuous spectrum with a maximum at 510 millimicrons. It responds almost instantaneously to changes in current flow so that it may be regarded as providing square wave flicker.

The apparatus had four frequency ranges giving continuously variable flicker from 5 to 120 cps. The scale of the frequency dial was calibrated by means of an audio-oscillator and an oscilloscope. By setting the frequency dial and varying the audio-oscillator to eliminate beat, the output frequency of the flicker generator was measured at 15 points in each range. The calibration of the remainder of the scale was completed by fitting an equation to these points.

The flicker generator had a device to ensure the constancy of the calibration. An electron ray tube was provided as a beat-frequency indicator for comparing the output of the generator against the 60-cycle line frequency. Before and after each experimental session, the frequency scale was set to 60 cycles and the beat in the electron ray tube eliminated. It was found that the flicker-generator output remained stable during periods longer than the experimental sessions.

The glow modulator tube was mounted in a housing which included a flashed opal disc. This arrangement provided a circular stimulus patch of uniform brightness 9 mm. in diameter. The brightness of the stimulus patch was calibrated on a bar

photometer against a standard lamp. The brightness was found to be 265 millilamberts (2.42 log mL.). A switch was inserted in the lead to the glow modulator so that the duration of the stimulus exposure could be controlled by the experimenter.

The auditory stimulus was obtained from a random-noise generator. The output was led through an electronic switch to the headphones. The switching circuit was triggered by the flicker generator, so that the auditory flutter followed the frequency of the visual flicker. Since the auditory flutter had to be the same under either phase condition, a 50:50 light-dark ratio was used throughout.

The phase relations of the flutter and flicker were controlled in the electronic switching unit. The auditory flutter could be either in phase or 180° out of phase with the visual flicker. When continuous noise was required, the headphones were coupled directly to the random-noise generator.

HS 33 headphones with ear caps were used. The noise level at the headphone was measured with a Massa artificial ear unit. Two levels of noise were used, 80 and 90 db. re 0.0002 dynes/sq.cm.

The glow modulator and housing were mounted on a stand at eye level, 105 cm. from the subject, so that the circular test patch subtended a visual angle of 30 minutes. Three brightnesses were used, 2.42, 1.42, and 0.42 log mL. Neutral filters of density 1.0 and 2.0 were mounted on stands so that they could be interposed between the subject and the test patch. A head rest was provided to ensure that the subject remained a constant distance from the stimulus. Binocular central vision was used throughout.

Experimental Design

The experimental variables are summarized below. The symbols used in subsequent discussion are shown in brackets.

1. *Intensity of noise*
   - (*a*) 80 db. .... (i_1)
   - (*b*) 90 db. .... (i_2)
2. *Brightness*
   - (*a*) 2.42 log mL. .... (b_1)
   - (*b*) 1.42 log mL. .... (b_2)
   - (*c*) 0.42 log mL. .... (b_3)
3. *Noise patterns*
   - (*a*) No noise .... (n_0)
   - (*b*) Continuous noise .... (n_1)
   - (*c*) Auditory flutter in phase .... (n_2)
   - (*d*) Auditory flutter out of phase .... (n_3)

The experiment was treated as a $2 \times 3 \times 4$ analysis of variance with subjects as replications. The 24 treatment combinations were laid out in a split plot (**5**, **11**) in order to minimize the effect of variation of a subject's CFF during the experimental session.

This design was particularly suited to the present experiment since interest was centred primarily on comparisons of the four noise patterns and their interaction with the other two variables. The first split was for intensity of noise and the second for brightness level.

The absence of noise, n_0, was a dummy treatment with respect to intensity of noise, since comparisons of treatment combinations involving n_0 could not reflect differences between the effects of the two intensity levels of noise. Therefore, values

involving n_0 were omitted in computing the sums of squares associated with intensity of noise and its interactions according to the method given by Quenouille (11).

Procedure

Eight young adult subjects were used, seven male and one female. None of the subjects wore spectacles and only one reported any auditory deficiency. This subject was partially deaf in one ear, a deficiency which appeared to have no influence on his responses.

The subjects wore red goggles for ten minutes before entering the dark room. They were adapted in darkness for twenty minutes before testing began.

The CFF was measured by the method of limits. When the stimulus field was first exposed, the stimulus frequency was higher than the CFF so that the field appeared steady. The frequency was decreased at a constant rate and when the subject reported verbally the first appearance of flicker, the scale reading was noted. The CFF was based on the mean of four such readings.

The scale values are a function of the reciprocal of frequency, so that the rate of change of frequency was not equal for each threshold measured; within the range required for measurements at any one level of brightness, however, the scale closely approximated a linear function of frequency. For b_1, b_2, and b_3 the size of a scale value was approximately 0.24, 0.15, and 0.17 cps., respectively.

Landis (9) has reviewed the literature on CFF and its related variables. He refers to unpublished data showing that the length of time a subject is exposed to a flickering light will affect CFF. An exposure of the stimulus field of the order of three to five seconds was recommended. In the procedure used here, the stimulus was exposed for periods of six to twelve seconds. The long exposure was necessary since no ready signal was given; as the appearance of the stimulus was the only signal to the subject, extra time was required to ensure that he was attending. To prevent the subject from reaching a time rather than a visual judgment, the starting frequency was varied.

Results

In order to eliminate heterogeneity of variance, the analysis was performed on the log CFFs. The analysis of variance is shown in Table I.

Because this experiment was designed to answer certain specific questions, the over-all noise pattern mean square is of little interest. Three sums of squares were calculated, using the method described by Cochran and Cox (5), for the specific comparisons which would provide the required answers. The first was the comparison of n_0 and n_1, giving the answer to question 2 on the effects of continuous noise on CFF. The second compared n_2 and n_3, the in-phase and out-of-phase conditions and gave the answer to question 1. The third compared $\frac{1}{2}(n_2 + n_3)$ with n_1—the average effect of interrupted noise with the effect of continuous noise—providing the answer to question 3. The interactions of these noise-pattern comparisons with brightness and intensity of noise provided the answer to question 4.

It may be noted that the sums of squares for the specific comparisons do not sum to the total sum of squares for noise-pattern differences. This

TABLE I

ANALYSIS OF VARIANCE OF LOG CFF

Source	df	Sum of squares*	Mean square	F
Subjects	7	70524		
Intensity of noise (I)	1	89	89	<1
Error_1	7	9564	1366	
Brightness (B)	2	2030580	1015290	
B × I	2	358	179	<1
Error_2	28	20285	724	
Noise patterns (N)	3	906		
N_1: n_0 *vs.* n_1	1	31.5	31.5	2.3
N_2: n_2 *vs.* n_3	1	337.5	337.5	24.6**
N_3: n_1 *vs.* $\frac{n_2+n_3}{2}$	1	368.5	368.5	26.9**
N × I	2	0		
N × B	6	67		
$N_1 \times B$	2	11.0	5.5	<1
$N_2 \times B$	2	42.2	21.1	1.54
$N_3 \times B$	2	53.3	26.7	1.95
N × B × I	4	44	11.0	<1
Error_3	105	1441	13.7	
Dummy treatments	24	4971	207.1	
Total	191	2138829		

*All sums of squares have been multiplied by 10^6.
**Significant at the 1% level.

follows since the third component is not orthogonal to the other two. The resultant lack of independence of the three components does not vitiate the validity of the tests of significance, since the tests are based on *a priori* decisions. Tests of significance applied to the component sums of squares listed above provided answers as follows:

1. CFF is higher with in-phase flutter than with out-of-phase auditory flutter; the difference is significant at the 1% level.

2. CFF is not changed significantly by stimulation with continuous noise.

3. CFF in the presence of interrupted noise is higher than with continuous noise, the difference being significant at the 1% level.

4. None of the effects tested varies significantly with brightness or with intensity of noise.

Although the two noise intensities are not significantly different in their effect on CFF, this comparison is of low precision and no conclusions on the effect of intensity of noise within the present experiment are possible. The intensity-of-noise mean square was in fact surprisingly small compared with $error_1$, but it was found that there was an order effect which accounted for this result. With seven of the eight subjects, the CFF decreased from the first half of the experimental session to the second.

The mean CFFs for each noise pattern and brightness are presented in Table II.

TABLE II

MEAN CFF IN cps. OF 8 SUBJECTS WITH 4 NOISE PATTERNS AT 3 LEVELS OF BRIGHTNESS

Brightness (log mL.)	Noise patterns			
	No noise (n_0)	Continuous noise (n_1)	Interrupted noise: In-phase (n_2)	Interrupted noise: Out-of-phase (n_3)
2.42	38.52	38.74	39.00	38.76
1.42	29.88	29.93	30.23	30.04
0.42	21.61	21.64	21.97	21.69

Evaluation of the Experimental Design

The success of the split-plot design used in the present experiment depended upon the validity of the assumption that CFF would vary appreciably during the experimental session. Inspection of the three error mean squares in the analysis of variance in Table I gives evidence that the assumption was valid, since $error_3$, derived from comparisons within a twenty-minute period, is markedly smaller than the other two.

Further evidence is provided by the relatively large sum of squares associated with comparisons among the dummy treatments. This sum of squares in fact represents comparisons of CFFs measured in different twenty-minute periods.

Discussion

That auditory flutter in phase with a flickering stimulus will produce a higher visual CFF than out-of-phase auditory flutter is a clear demonstration of the existence of a central mechanism for the integration of the neural impulses from the two sense organs as hypothesised by Sherrington.

Intersensory effects have often been attributed to "attention," since

momentary stimulation in one sense modality may serve to make the subject more alert to the presentation of a stimulus in another sense modality. No such explanation can account for the present results. The measurement of CFF did not involve brief exposures. In addition, the in-phase and out-of-phase conditions differed only in the temporal relation of the interruption of the visual and auditory stimuli.

Preliminary tests indicated that under no condition used in this experiment could the subjects distinguish the two phase conditions. Even at frequencies as low as 5 cps. this discrimination was still impossible.

The simplest account of the present results is in terms of the concepts of summation and inhibition. The discrimination of flicker by the eye depends on the temporal resolving power of the nervous system. Fusion occurs when successive flashes can no longer be resolved. Under the in-phase condition of auditory stimulation, the bursts of noise are simultaneous with the flashes of light so that the neural excitation resulting from each flash is enhanced, thereby facilitating the discrimination of flicker. On the other hand, under the out-of-phase condition, the burst of noise exactly filled the gap between two light flashes, so that the difference in neural excitation between the light flashes and the dark periods between them would tend to be diminished. Consequently, the discrimination of flicker would be impaired.

Although there was a significant difference between the in-phase and out-of-phase conditions, the actual amount of the difference was small. At the most it was 0.5 cps. and on the average about 0.20 cps. Baker and Bott (4) had found differences around 2 cps. between synchronous and asynchronous binocular flicker. It is not surprising that there is less interaction between the eyes and ears than between the two eyes.

In contradiction to Kravkov's results (8), it was found that stimulation by continuous noise did not affect CFF significantly. However, Kravkov noted that auditory stimulation was most effective at its onset and that adaptation was rapid. In the present experiment, the four readings on which CFF was based were obtained in about three minutes, and during this period there was continuous stimulation by noise. It follows, then, that the effects of auditory stimulation as described by Kravkov might not be apparent.

The results of the present experiment show that auditory flutter will increase CFF whereas continuous noise will not. No explanation can be offered.

Summary

The interaction of auditory and visual stimulation was investigated by a modification of the method used by Sherrington to study the binocular

fusion of flickering stimuli. Visual critical flicker frequency was measured (*a*) in the absence of noise, (*b*) in the presence of continuous noise, (*c*) with auditory flutter (interrupted noise) in phase with the visual flicker, (*d*) with auditory flutter out of phase with the visual flicker, at three levels of brightness and with two intensities of noise.

It was found that the frequency at which flicker was first detected was higher in the presence of in-phase auditory flutter than with out-of-phase auditory flutter. In addition, interrupted noise increased CFF although continuous noise did not.

The former result led to the conclusion that there is neural interaction between vision and audition consonant with Sherrington's concept of the final common path.

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INDIVIDUAL DIFFERENCES IN PAIN THRESHOLDS[1]

JAMES W. CLARK[2] AND DALBIR BINDRA
McGill University

IN THE PAST couple of decades a variety of studies dealing with pain thresholds have been reported. Some of these studies have been concerned with thermal-pain thresholds, others with electrical- or pressure-pain thresholds. Some investigators have used uninstructed and naïve subjects, while others have used subjects who were both sophisticated and specifically instructed. Except for a series of studies (5) in which a small number (three) of highly sophisticated and instructed subjects was used, the most striking finding in these various studies has been the marked individual differences in thresholds obtained under identical instructions and conditions of stimulation. The present study aims to throw some light on the source of these individual differences.

The problem is approached by comparing the reactions of the same subjects to three different types of noxious stimulation: heat, electric current, and pressure. Two aspects of the response to painful stimulation are studied: *pain threshold* and *tolerance level.* The latter term refers to the maximum intensity of the noxious stimulation to which the subject is willing to expose himself. It was hoped that comparison of these two measures under three types of pain stimulation would clarify the nature of the observed individual differences.

METHOD

Subjects

The Ss were 46 normal adult males who had volunteered for service in the Canadian Army. All Ss had completed at least 7 years of schooling; they ranged in age from 17 to 30 years.

Apparatus

The apparatus consisted of three stimulators, each designed to deliver to S's arm controllable noxious intensities of electric current, pressure, or radiant heat.

Electric stimulator. The voltage for stimulation was obtained from the 110-volt, 60-cycle power line through a variac and a step-up transformer, the output of which could be varied between 0 and 4500 volts. The current through S was limited by a series resistance of 1.5 megohms. As the resistance of S was negligible in comparison with 1.5 megohms, a close approximation to the current passing through S is given

[1]This research was supported by a grant to Professor D. O. Hebb from Foundations Fund for Research in Psychiatry.

[2]Now at Queen's University, Kingston.

by dividing the transformer output-voltage by the value of the series resistance. The variac output could thus be calibrated in terms of milliamperes (ma.) of current through S, and could be varied from 0 to 3.0 ma. The voltage across S was measured by a high resistance vacuum-tube voltmeter, and was multiplied by the current to give the wattage developed across S.

Electrodes of 1.8 cm. in diameter were fastened to the radial and ulnar surfaces of S's forearm by means of an elastic band. The electrodes and S's arm were smeared with electrode paste.

Starting with the zero position, the transformer output was increased at a slow constant rate (approximately 0.1 ma. per second). The S signalled his pain threshold and his tolerance level by depressing a reaction key. The data were recorded in milliamperes, volts, and watts. As the amperage, voltage, and wattage measures proved to be highly intercorrelated (.92 and above), the wattage alone is reported here.[3]

Mechanical stimulator.[4] Plates of hard rubber spikes were sewn into the sleeve of a standard clinical sphygmomanometer. The plates were arranged to fit the curvature of the arm, and the spikes which projected from the plates were sufficiently blunt not to perforate the skin even at maximum pressure.

The sleeve of the sphygmomanometer was wrapped around S's upper arm in such a way that one set of projections lay against the brachial surface of the upper arm and the other set lay against the deltoid surface. The projections were pressed against the arm by increasing the sphygmomanometer pressure at a slow, constant rate (approximately 5 mm. Hg./sec.) until the pain threshold and the tolerance level had been reached. S reported these thresholds verbally. The data were recorded in mm. Hg.

Radiant-heat stimulator. A 250-watt infra-red lamp served as the heat source. The lamp was contained in an asbestos-lined box into which S's forearm was clamped. The ulnar surface of the forearm was brushed with lamp black to insure a high degree of absorption independent of degree of skin pigmentation. The radiation from the lamp fell on the ulnar surface of S's arm, 20 cm. away, through an aperture of 2.0-cm. diameter. The intensity of radiant heat was approximately 116 mc/sec/cm^2. A stopwatch was started by *E* when the lamp was turned on, and the time recorded when S depressed a reaction key to signal. The pain threshold and the tolerance level were recorded in number of seconds from the onset of stimulation.

The apparatus was calibrated in mc/sec/cm^2 by a calorimeter which entailed the use of a copper-constantan thermocouple. The radiant-heat stimulator gave a linear heat rise over the maximum exposure time (45 sec.), making possible a direct conversion of data from units of seconds to mc/sec/cm^2. An upper-limit stimulus duration of 45 sec. was established when it was found that (*a*) irreversible tissue damage occurred above this exposure, and (*b*) Ss who tolerated a stimulus duration of 45 sec. invariably tolerated much longer exposures. Presumably, at 45 sec. or slightly before, "ceiling pain" was reached, beyond which greater stimulus intensities caused no perceptibly greater pain (8).

Between trials, the apparatus was ventilated with a fan. Successive trials were given on adjacent areas of the same forearm.

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[3]Hill *et al.* (9) found that estimated intensities of shock correlated more highly with the apparent delivered wattage than with amperage.

[4]This instrument was constructed by Dr. E. G. Poser. We are indebted to him for its use.

Procedure

The pain threshold and the tolerance level for electrical, mechanical, and thermal stimuli were determined in that order for each S. The instructions were as follows:

"The intensity of current (pressure, heat) is going to increase gradually. You are to press the reaction key down as soon as you feel the first signs of pain. I don't mean when it really starts to hurt; I mean when you start to feel a sensation that could be described as pain-in-the-slightest-degree. After this release the key. The stimulation will continue. Press the key down for the second time when you have had enough and want the current (pressure, heat) turned off. This is not to see how much you can take. As soon as you press the key the second time the stimulation will stop."

The instructions were not elaborated upon, even for the few Ss who reported difficulty or confusion in identifying the pain threshold. The Ss were given no training. Two trials with the electric stimulus (each trial yielding a measurement of both the pain perception threshold and the tolerance level) were followed by two trials with the mechanical stimulus and two trials with the thermal stimulus. Approximately five minutes were allowed between all trials.

Results

In some cases maximum stimulus intensity was reached before S reported the pain threshold or the tolerance level. For purposes of computing the means and standard deviations, these Ss were given maximum scores; they were omitted for computation of rank-order correlation coefficients, which would have been spuriously higher had they been included.

As there was no significant difference between the means of the first and second trials at either pain threshold or tolerance level for any of the three stimuli, these two values were averaged to give each S's pain threshold and tolerance level for each type of stimulation. The immediate retest reliabilities of the threshold and tolerance level for the three methods were around .85 (see Table III). The following are the main results:

1. The individual differences in the pain threshold as measured by all three methods were considerable (Table I), the standard deviations being from 46 to 141 per cent of the mean. Thermal-pain thresholds were less variable than mechanical-pain thresholds; electrical-pain thresholds were most variable. Three Ss failed to report pain thresholds at the maximum electrical intensity, and one S did not report pain at the maximum heat exposure.

2. The tolerance levels were slightly less variable than the pain thresholds (Table II). This may have resulted from the limit on maximum intensity of the stimuli, which prevented measurement of the tolerance level of 10 Ss with the electrical method, and of 5 Ss with each of the mechanical and the thermal methods.

3. The pain thresholds as measured by electrical, mechanical, and

TABLE I

Distributions of Pain Thresholds, Measured by Electrical, Mechanical and Thermal Methods ($N = 46$)

	Type of noxious stimulus		
	Electrical (watts)	Mechanical (mm. of Hg.)	Thermal (sec.)
Mean	10.1	53	13.6
Median	4.2	33	13.0
Standard deviation	14.2	45	6.3
Coef. of variability	141%	85%	46%
Range	0.2–63.8	8–200	4.0–45.0
Skewness $\left(\frac{\text{median-mean}}{SD}\right)$	−.42	−.45	−.10

TABLE II

Distributions of Tolerance Levels, Measured by Electrical, Mechanical, and Thermal Methods ($N = 46$)

	Type of noxious stimulus		
	Electrical (watts)	Mechanical (mm. of Hg.)	Thermal (sec.)
Mean	29.1	142	23.4
Median	25.0	135	20.0
Standard deviation	21.6	63	10.1
Coef. of variability	74%	44%	43%
Range	0.4–63.8	33–300	12.1–45.0
Skewness $\left(\frac{\text{median-mean}}{SD}\right)$	−.18	−.12	−.34

thermal methods were all significantly intercorrelated (Table III). The electrical, mechanical, and thermal intensities were somewhat more highly intercorrelated at the tolerance level than at the pain thresholds.

4. There were significant positive correlations between the pain thresholds and the tolerance levels (Table III). The distributions of the pain thresholds and the tolerance levels were also similar.

In addition, it may be noted that the median pain threshold for the radiant-heat stimulus of approximately 116 mc/sec/cm^2 (13.0 sec.) was about the value expected by interpolation from a graph by Hardy, Wolff, and Goodell (5, p. 124) on which the pain threshold is plotted against the intensity of the stimulus (in mc/sec/cm^2) and the duration of the stimulus in seconds.

TABLE III

RANK ORDER CORRELATIONS BETWEEN ELECTRICAL, MECHANICAL, AND THERMAL MEASUREMENTS OF PAIN THRESHOLD AND TOLERANCE LEVEL

($N = 46$)

		Pain threshold			Pain tolerance level		
		Electrical	Mechanical	Thermal	Electrical	Mechanical	Thermal
Pain threshold	Electrical	.81*	.77	.58	.63	.56	.44
	Mechanical		.91*	.67	.56	.72	.50
	Thermal			.88*	.44	.50	.64
Pain tolerance level	Electrical				.91*	.78	.65
	Mechanical					.86*	.73
	Thermal						.85*

*Immediate retest reliability.

DISCUSSION

We have noted marked individual differences in pain thresholds, and high correlations between pain thresholds measured by electrical, mechanical, and thermal methods. We are concerned here with the possible sources of the observed individual differences.

Variables in each of three main classes have been proposed by some investigators to account, in part at least, for the lack of uniformity of the pain threshold: 1. *Peripheral nonsensory factors*, i.e., lack of adequate control of the physical proximal stimulus (**2, 5, 9**). The critical stimulus for pain is not known. It is therefore not possible to describe the exact intensity of the adequate stimulus. Retest reliabilities are usually low when mechanical or electrical stimuli are used, and doubt has been cast upon the validity of the physical measures. 2. *Sensory factors*, e.g. density of pain receptors, presence of myelinated or unmyelinated pain fibres, etc. (**5, 10, 12**). 3. *Attitudinal factors*, e.g. "emotional instability," attitudinal variables associated with sex and cultural differences, form of instructions, etc. (**3, 11**). What is the relative importance of these factors in producing the individual differences?

Hardy, Wolff, and Goodell (**5, 6, 7**) have demonstrated that, under optimal conditions of measurement and training, the pain threshold is uniform both between individuals and on all skin surfaces of the body. Although this is not a typical finding, yet the very fact that it is possible to obtain uniform thresholds eliminates sensory variables as necessary contributors to the individual differences reported by the majority of

investigators. Thus, individual differences in pain thresholds should be accountable in terms of the remaining two classes of variables: peripheral nonsensory variables (uncontrolled variability in the critical pain stimulus) and attitudinal variables.

It is unlikely that the peripheral nonsensory variables which influence the measurement of the threshold with one type of noxious stimulus would have a similar influence upon the threshold when measured by another type of noxious stimulus. For example, the following peripheral factors have either been shown to affect the pain threshold, or been postulated to explain individual differences, when the stimulus is radiant heat: skin temperature (**1**, **4**), skin wetness (**5**), degree to which the radiated surface is blackened (**2**), and variable hyperalgesia due to the number of exposures required to measure the threshold (**13**). It can hardly be expected that these nonsensory variables influencing thermal-pain thresholds should have the same effect on the pain threshold when it is measured by electrical or mechanical stimuli. Hence the variability *common* to pain thresholds measured by electrical, mechanical, and thermal stimuli (expressed by their intercorrelations) cannot be accounted for in terms of peripheral nonsensory variables. It must be attributed to attitudinal factors. (The variability *peculiar* to measurement with any one kind of noxious stimulation may, of course, result from peripheral nonsensory variables and any attitudinal variables specific to that type of stimulation.)

Thus we conclude that the individual differences in the pain threshold are in large part attributable to attitudinal variables which are independent of the type of noxious stimulus used.

The term "attitudinal variables" is a broad one. It refers, at one extreme, to cognitive variables such as the "definition" of pain and set and, at the other extreme, to affective variables such as anxiety or timidity. Hardy, Wolff, and Goodell (**5**) have suggested a variable of the cognitive type to account for the individual differences and discrepancies in mean pain thresholds reported by other investigators using thermal stimulation.

Three pain qualities (pricking, burning, and aching), each having a distinct, measurable threshold, have been identified by Hardy *et al.* (**5**). They then account for individual differences in the pain threshold by postulating that some Ss signal their threshold at the "burning" pain threshold, others at the "pricking" and "aching" pain thresholds. If their explanation were correct and sufficient, one would expect a trimodal frequency curve of the distribution of pain thresholds, with Ss grouped around each of the three supposedly uniform thresholds, when no instruction concerning the quality of the sensation to be reported as "pain" is

given. In the present experiment, however, the distributions of the thermal-pain thresholds were unimodal. Even if there are in fact three distinct pain qualities, their existence cannot wholly account for the observed individual differences in the pain threshold.

More insight into the nature of these individual differences can perhaps be obtained by considering the tolerance-level data. High correlations were found between the pain threshold and the tolerance level (Table III). The size of these correlations suggests that the factors contributing to individual differences in the pain thresholds and tolerance levels are largely the same. Now, it seems reasonable to assume that the tolerance level of an individual is chiefly a function of his emotional makeup. And if we assume that individual differences in the tolerance level are determined by affective factors, the attitudinal variables underlying individual differences in the pain threshold would also appear to be affective rather than cognitive in nature. We are inclined to favour such an interpretation.

Summary

The pain thresholds and tolerance levels of 46 uninstructed and untrained Ss were measured with electrical, mechanical, and thermal stimuli. There were wide individual differences in all measures. High intercorrelations were found between the electrical, mechanical, and thermal measures, and between the pain thresholds and tolerance levels.

On the basis of these results it is suggested that lack of control of the physical proximal stimulus is insufficient to account for the individual differences in pain thresholds. The conclusion reached is that attitudinal variables are responsible for a large part of the individual differences in both pain threshold and tolerance level, and that these attitudinal factors are primarily affective rather than cognitive in nature.

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RETINAL GRADIENTS OF OUTLINE DISTORTION AND BINOCULAR DISPARITY AS STIMULI FOR SLANT[1]

W. C. CLARK,[2] A. H. SMITH, AND AUSMA RABE[2]

Queen's University

THE EARLIER STUDIES in this series have supported Gibson's general position (5) that, in perceiving distance and depth, the object, its projected gradient of change on the retina, and the percept are in psychophysical correspondence. More specifically, retinal gradients projected by inclined textured surfaces (1, 3) and rectangular outline forms (2) were found to be sufficient stimuli for perceiving slant under experimental conditions which made other visual and non-visual cues ineffective. The present study represents an extension of the same general method to two other variables, both expressible in terms of retinal gradients of stimulation. Outline distortion may be regarded as a more general stimulus condition than outline convergence produced by slanted rectangles (2). The retinal projections of more complex forms are difficult to draw, but a relatively simple case is a circle slanted about a vertical axis, of which the retinal image is an ellipse.

Hitherto in these experiments the observers employed only monocular vision. It has been suggested (5, pp. 100–110) that the disparity between the two retinal images, of either a textured surface or an outline form, constitutes an effective gradient of stimulation. The experimental isolation of cues provided by the extrinsic eye muscles from retinal cues is very difficult. A test of binocular vision was included in order to explore the contribution to accuracy of perception of this factor added to the other factors which were operative. It will be clear that the extent to which a gradient was effective in this case requires further study.

A third objective was to test once more the view, unconfirmed in the earlier studies, that accuracy of perceiving slant increases with an increase in the number of gradients present. The relevance of this point to the problem of constancy was discussed in an earlier paper (3).

[1]This is the fourth of a series of papers on the role of retinal cues in the perception of slant. The earlier studies were reported by Clark (1) and in this journal (2, 3). This study was supported by a grant from the Defence Research Board, Canada (Project DRB 370).

[2]Mr. Clark is now at the Vision Research Laboratory, University of Michigan. Miss Rabe is at the Department of Psychology, University of Michigan.

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Method

The experimental arrangements were similar to those described earlier (1, 2, 3) namely: an adjustable head-rest and eyepiece, in this case permitting monocular or binocular vision; a neutral grey reduction screen with a circular viewing aperture fitted with a shutter to screen the stimulus between trials; and a homogeneous black background in the frontal-parallel plane 175 cm. from *O*'s eye. There were four stimulus conditions (Figure 1). Condition A, *film-field*, was produced by a sheet of

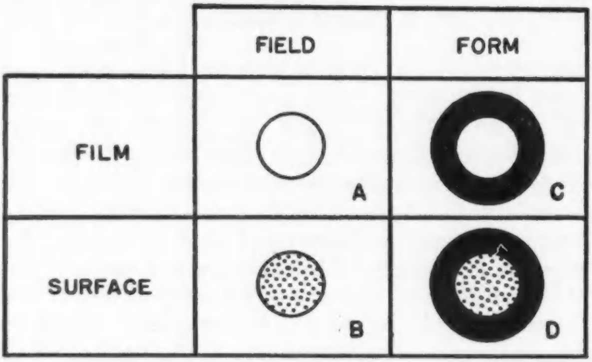

FIGURE 1. Diagram of the stimulus conditions.

wallboard, 88 × 113 cm., painted flat white. This appeared through the aperture as a field without an edge filling the visible area. Condition B, *surface-field*, was an arrangement like A except that the field was constituted by dark blue cloth covered with white circular dots, 6 mm. in diameter and with centres 11 mm. apart. Condition C, *film-form*, was a white circle with a textureless surface against the black ground. Condition D, *surface-form*, was a white circle, dotted like the field in B, against the black ground. The two forms were 26.5 cm. in diameter.

For monocular vision, the two forms were exposed on a holder 12 cm. in front of the background, centred in the visual field, and were viewed through a circular reduction-screen aperture, 11.7 cm. in diameter, 32.8 cm. from the eye. The two fields were slanted about a vertical axis 12 cm. in front of the normal position of the ground, which was removed in these cases, and were viewed through an aperture of 6-cm. diameter so that the visible area was equal to that of the forms. For binocular vision the viewing conditions were the same for the two forms. For the two fields, an additional screen, 68.8 cm. from *O*'s eye, with a viewing aperture 13.2 cm. in diameter, was used to make the visible area of each field the same as for monocular vision, and approximately the same as the area of the two forms.

The *O*s recorded their judgments by moving a pointer on an ungraduated circular dial on the table in front of the head-rest. This was coupled with a graduated dial on *E*'s side of the reduction screen.

Illumination was indirect, centred behind *O*, and was decreased below the point at which there were observable irregularities in the film-surfaces. Black cloth screens were used to make uniform the reflectance from the surfaces of the room and to eliminate gradients of brightness from the stimulus surfaces.

The *O*s were 16 college students. Each *O* had a different random order of the four

conditions for each mode of vision, and each made six judgments for each condition, a total of 48 responses. The order was counterbalanced for a given *O*; for example, three trials in the order, C, B, D, A, and three in the reverse order. Half the *Os* employed monocular vision first, the other half binocular vision first. The stimuli were inclined 40 degrees from the frontal-parallel plane with the left edge nearer to *O*. This angle was changed at random to one of 18 others to prevent set-formation, but the responses to these were not recorded. Judgments were recorded to the nearest degree, the index of accuracy being the difference between objective and perceived slants. At the end of a session, *O* was asked whether he had perceived circles or ellipses.

Results

The mean perceived slants were less than the objective slant (Table I), but the two gradients, outline distortion and surface texture compression,

TABLE I

Mean Perceived Slant
(Stimulus slant 40 degrees; each mean based on 96 observations)

Vision	Stimulus condition			
	A	B	C	D
Monocular	.13	9.70	24.30	21.37
Binocular	−.07	17.12	32.47	29.51

were sufficient stimuli for perceiving slant. Outline was a more potent cue than surface texture. The addition of texture to outline (comparison C–D, Table II) did not significantly increase accuracy of perception with either mode of vision. Also, C differed from A, and D from B, only in terms of outline.

Binocular perception was more accurate for all conditions yielding slant. The t ratios and p values for each condition are as follows: B, $t = 2.36$, $p = .05$; C, $t = 3.23$, $p = .01$; and D, $t = 3.13$, $p < .01$. However, monocular perception of the film-form was superior to binocular perception of the surface-field ($t = 5.50$, $p = .005$). Here, the only two competing parameters were surface texture and outline.

Eleven of the *Os* served in a previous experiment (3) under the same experimental conditions except that the forms were rectangles, rather than circles, and there was one other qualification indicated in the next section. A comparison of the mean monocular percepts for the figures differing only in shape in the two experiments showed that outline distortion produced by a slanted circle was a more effective cue for slant than outline convergence. The circular film-forms were perceived as more slanted than the rectangular film-forms by 10.52 degrees on the

TABLE II

Significance of Mean Differences in Perceived Slant for Selected Pairs of Stimulus Conditions

($df = 15$)

(The t ratios were computed by the method of paired comparisons [4, p. 105])

Comparison	Monocular		Binocular	
	t ratio	p value	t ratio	p value
A–C	9.83	.005	13.45	.005
B–D	6.40	.005	4.87	.005
C–D	2.01	>.100	1.77	>.100

average ($t = 5.02$, $p = .005$). The mean difference for the corresponding surface-forms was 9.62 degrees in the same direction ($t = 2.75$, $p = .025$).

The replies of the *O*s to the question concerning the shape of the distal stimulus were unequivocal. All of them claimed to have seen slanted circles, not ellipses.

Discussion

The results generally support Gibson's concept of psychophysical correspondence mediated by gradients of retinal stimulation, especially in the cases of outline distortion and surface texture. The results indirectly suggest that retinal disparity functions similarly. The correspondence between the analysable aspects of the objective forms, their projected correlates on the retina, and the percepts was ensured by the experimental arrangements.

The superiority of outline distortion over outline convergence requires further confirmation, since there may have been a practice effect from the first to the second experiment. The role of practice has not yet been evaluated in this context. The 11 *O*s who viewed both rectangles and circles viewed the latter about a month later. An independent test (results unpublished) in which 12 different *O*s received all the stimuli of both experiments under conditions which counterbalanced practice indicated generally that circular forms were perceived more accurately than rectangular forms, but in terms somewhat less positive than those reported here. The point also needs testing with a variety of rectangles, including a square, equal in area to the circle, and for a range of angles of slant.

There is no basis in the data for evaluating the superiority of binocular vision. Retinal gradient, either of texture or form, was essential to depth perception but retinal disparity was not. This is provocative in view of the belief, based on much experimentation, that the stereoscopic effect

is the most important basis for depth perception. A further point of interest in this context is that slant was perceived less accurately binocularly than monocularly in one comparison (B–C); this may be a product of the potency of outline over texture, which binocular vision apparently did not offset. However, the fact that the best mean binocularly perceived slant was about 7½ degrees less than the objective slant suggests that there were unevaluated variables affecting binocular vision which were not operating maximally in these conditions. On the other hand, the significant interaction between retinal disparity and the other variables, in contrast with its previous absence in these experiments, makes questionable the propriety of interpreting retinal disparity as a gradient. Its effect on slant perception may have been produced by sensations of convergence. Clearly, we would be able to evaluate the role of this factor more adequately if we could define the order of effectiveness of the purely retinal cues.

The data fail to support the invariance hypothesis if this can reasonably be assumed to apply to such impoverished situations. The circular form was seen as a slanted circle, never as an ellipse, but the slant was perceived inaccurately. This superficially innocuous outcome poses a difficult question for the traditional explanation of constancy, and has been discussed in detail elsewhere (3).

Summary

Sixteen *Os* viewed monocularly and binocularly a film-field and a surface-field (both without outline), a film-form, and a surface-form, all circular stimuli inclined 40 degrees from the frontal-parallel plane, under conditions which generally offered only retinal cues. Perception of slant was a function of gradients of surface texture and of outline distortion, as required by the theory of psychophysical correspondence. These gradients did not interact to make perception more accurate, but retinal disparity interacted with both of them. Outline and circles were better cues for slant than surface texture and rectangles, respectively. The latter comparison was based partly on data from a previous experiment.

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EFFECTS OF EARLY EXPERIENCE ON SOCIAL BEHAVIOUR[1]

RONALD MELZACK
University of Oregon Medical School

AND WILLIAM R. THOMPSON
Queen's University

PERCEPTUAL EXPERIENCE acquired early in life has been shown in many recent studies to have a profound influence on the intellectual (**9, 10**), perceptual (**8**), and emotional (**7**) behaviour of the mature organism. There is one area of mammalian behaviour, however, which is relatively unexplored: social behaviour. Reviews of animal studies by Beach and Jaynes (**1**) and Hebb and Thompson (**5**) point out the paucity of evidence on the effects of early perceptual and social experience on adult social behaviour.

Fredricson (**3**) has provided experimental evidence that mice raised with experience in competitive social situations show more aggressive behaviour at maturity than litter-mates raised without such experience. Similarly, a preliminary investigation by Clarke *et al.* (**2**) has shown that dogs deprived of normal social and perceptual experience during development are later consistently submissive to their normally reared littermates. Part of the present study, then, is an attempt to investigate more systematically the effects of early experience on dominance behaviour in the dog.

Clarke *et al.* (**2**) have also reported that normally reared dogs eagerly accept friendly approaches by humans while restricted dogs repeatedly withdraw from human attention. A method for analysing complex social and emotional behaviour of one species toward another has been described by Hebb (**4**). The wide range of emotional behaviour manifested by dogs (**7**) thus also permits an attempt to investigate the effects of early experience on the social and emotional responses made by dogs to experimenters acting in a "friendly," "bold," or "timid" manner toward them.

[1]This investigation was done at the McGill University Psychology Laboratory, and supported by grants from the Dominion-Provincial Mental Health Program, the Rockefeller Foundation, and the Foundations Fund for Research in Psychiatry. The authors gratefully acknowledge the advice and guidance of Dr. D. O. Hebb throughout this study, and the assistance of Drs. Woodburn Heron, Helen Mahut, and Harry Scott in carrying out some of the experiments.

Method

Subjects. Nine litters of purebred Scottish terriers, all descendants of one litter of the Bar Harbor strain, were used. Each litter was randomly divided into two groups. One group, containing a total of 21 dogs (14 males and 7 females), was placed in restriction cages. The 16 dogs (8 males and 8 females) which comprised the "free environment" or control group were raised normally as pets in private homes and in the laboratory.

Rearing. Three different methods of restriction, described elsewhere in detail (9, 10), were used during this study. (*a*) Four dogs were reared separately in ordinary metal dog cages, and were able to look out at the other kennel cages and dogs. But, apart from a monthly 15-minute grooming period, they were never removed from their cages. (*b*) Seven dogs were reared in cages which were covered with heavy cardboard. The only part of the laboratory room that these dogs could see was the ceiling directly above an air- and light-vent at the top of each cage. Two or three dogs were kept in a single cage; but the only contacts they had with human beings until maturity occurred briefly during the daily feeding and cleaning period. (*c*) Ten dogs were reared in complete social isolation in cages like those used in (*b*). Only one dog was kept in a cage, and contact with human beings was eliminated. Each cage contained two compartments, and when the sliding partition between them was opened once a day, the dog was allowed to enter a freshly-cleaned compartment containing a pan of food. By means of these three methods, then, 21 dogs were deprived of a normal social and sensory experience from the time when weaning was completed at the age of four weeks until they were removed from their cages at from seven to ten months of age.

After the restricted dogs were released from their cages, they received the same opportunities for social and sensory stimulation as their normally reared litter-mates. They had long walks and play periods outdoors and in the laboratory, and had frequent contacts with other dogs and with human beings. Testing began about three weeks after the restricted dogs were released and was completed within six months. Since the litters used in this study were born at different times over a five-year period, it was not possible to use each litter for all of the tests.

Experiment I: Social Relations with Dogs (Dominance)

Subjects. Twenty-one restricted and 15 free-environment dogs were used.

Procedure. To test for dominance behaviour (6), a restricted and a normally reared dog, both food-deprived for 24 hours, were held at two opposite corners of the testing room by two experimenters. Either a large bone or a dish of food was located at the centre of the floor. Both dogs were brought up to the food and allowed to smell it. They were then returned to their corners and released at the same time.

The results for each contest, which lasted for five minutes, were classified as a *win* for one of the dogs, or a *tie*. A dog scored a *win* when he drove the second dog away from the food by growling or barking, and remained in control of the food for all or most of the time. A *tie* was recorded when the contest did not yield manifest dominance on the part of either dog.

In order to test only dogs of like ages, dominance contests were held within each of four groups of restricted and free-environment dogs. The number of dogs in each group is shown in Table I. There were approximately the same number of males and females among the restricted and free-environment dogs of each group.

TABLE I

NUMBER OF WINS MADE BY FREE-ENVIRONMENT (F) AND RESTRICTED (R) DOGS IN DOMINANCE TESTS

	N		No. of contests	Wins		Ties
	F	R		F	R	
Group 1	4	5	20	15	5	0
Group 2	2	5	10	7	1	2
Group 3	7	8	43*	35	1	7
Group 4	2	3	6	0	0	6
Totals	15	21	79	57	7	15

$\chi^2 = 41.62$
$p = .001$

*Some dogs were not tested because of the possibility of serious fights and the fact that some of the females were in heat at the time of testing.

RESULTS

Table I shows that the normally reared dogs made 57 "wins," as against 7 made by the restricted dogs. It is interesting to note that the highest number of wins made by restricted dogs occurred in Group I, in which two or three dogs were reared in a single restriction cage. The five wins made by these dogs were all scored against the same female control dog. However, no consistent sex differences could be discerned in the results. The difference in number of wins between restricted and control dogs for the four groups is significant at the .001 level.

The behaviour of the restricted dogs was such that the results cannot be attributed to their submissiveness alone; the dogs seemed also to be highly confused by the situation. Growling or snapping by the normally reared dogs, whose responses always seemed oriented toward the food and the competing dog, rarely elicited any comparable, organized, competitive behaviour in the restricted dogs. Indeed, most of them appeared unaware that there was any "contest." They tended to sit and watch the other dog eat, or to move off and explore the room. At times they went to the food when the dominant dog was present, but most often they

were easily pushed out of the way. Only occasionally did they compete by actually fighting.

Supplementary observations. The observations of sharing among restricted dogs reported by Clarke *et al.* (**2**) were confirmed in the present study. A number of contests were held between pairs of restricted dogs and between pairs of normally reared dogs. It was observed that when two restricted dogs were pitted against each other, they frequently shared the bone or food dish. Such sharing of food was only rarely observed among the normally reared dogs. Further evidence of the ineptitude of the restricted dogs in competitive situations was observed when they were tested against normally reared dogs which were six months younger. The restricted dogs consistently lost the bone or food to the younger control animals.

Experiment II: Relations among Dogs (Social Curiosity)

Subjects. Sixteen restricted and 11 normally reared dogs were used.

Procedure. Each dog was led into a testing room containing two dogs which were kept separately behind two wire-mesh barriers. Chalk lines were drawn 1½ feet in front of each barrier, and the amount of time during a 10-minute period which each dog spent across the chalk lines near the two other dogs was recorded. This test was repeated next day with the same dogs behind the barriers.

Results

On the first testing day, the normally reared dogs ran almost immediately to the dogs in the room. They sniffed and looked at them, sometimes growled and barked, and usually followed them closely on the other side of the barrier. They spent a mean of 97.7 seconds in such social investigation. During the remaining time they tended to explore the room or sit at a distance from the other dogs. On the second day, 9 of the 11 normally reared dogs spent less time near the two dogs than they did on the first (mean: 64.6 seconds): this suggests a diminution in "social curiosity" (**10**).

The restricted dogs, in comparison, showed a high degree of excitement in the presence of the dogs behind the barriers, but rarely followed them closely, or showed behaviour which seemed oriented with respect to these dogs. Indeed, a restricted dog would often wander close to one of the pens and urinate on it without taking any notice of the dog inside. At times the restricted dogs explored quietly around the room, then suddenly dashed toward one of the dogs in the barriers and spent considerable time running around in circles and moving rapidly back and forth, with gross, excited body movements, suggesting a diffuse emotional

excitement. They spent a mean of 64.5 seconds across the chalk lines close to the two dogs. This type of behaviour increased on the second day, without the emergence of more sustained, socially-organized curiosity behaviour. Eleven of the 16 restricted dogs spent more time across the line than they did on the previous day, giving a mean of 72.9 seconds. The difference in shift of means (Day 1 to Day 2) between the restricted and the normally reared dogs is significant at the .01 level of confidence ($\chi^2 = 6.68$).

Experiment III: Social Relations with Man

Subjects. Fourteen restricted and 14 free environment dogs were used.

Procedure. Three social roles, representing "typical" human behaviour toward animals (4), were played by an experimenter in the presence of each dog. (1) *Friendly man*: *E* tried to pat the dog and gently stroke his head and back. (2) *Timid man*: *E* retreated and tended to "cringe" after every approach that the dog made toward him. (3) *Bold man*: *E* moved directly and continually toward the dog with short, rapid, stamping steps. Each role was played for a period of two minutes, with about a five-minute interval between roles for recording the dog's behaviour.

Every attempt was made to present identical testing conditions to all dogs of both groups. *E* first walked slowly around the room for two minutes to make sure that no dog avoided him in advance of testing. The same *E* subsequently played all three roles, in the above sequence, to both the restricted and the normally reared dogs of any given litter. He was not told, prior to testing, whether a dog had been reared normally or in restriction, although this could sometimes be inferred from its behaviour.

The recorded observations of each dog's behaviour toward the "friendly man" and the "timid man" were tabulated under one of four categories of socio-emotional response: *friendly behaviour, avoidance, diffuse emotional excitement*, and *aggressive stalking*. The responses made to the "bold man" were classified as *avoidance* or *escape*.

Results

(1) *Behaviour to the "friendly man."* Thirteen of the 14 normally reared dogs showed *friendly behaviour* to the "friendly man" (Table II). They permitted *E* to pat them and play with them throughout the period; they approached at *E*'s call, and remained at his side, frequently turning onto their sides or backs while *E* stroked them. None of the restricted dogs showed this type of behaviour.

TABLE II

FREQUENCY OF EACH TYPE OF EMOTIONAL RESPONSE BY RESTRICTED (R) AND FREE-ENVIRONMENT (F) DOGS TO 3 SOCIAL ROLES PORTRAYED BY EXPERIMENTER

Categories of emotional behaviour	Type of social role					
	Friendly		Timid		Bold	
	R	F	R	F	R	F
Friendly behaviour	—	13	—	1	—	—
Diffuse excitement	10	—	2	2	—	—
Aggressive stalking	—	—	8	9	—	—
Avoidance	4	1	1	—	2	8
Escape	—	—	—	—	12	6
No emotional response	—	—	3	2	—	—
N	14	14	14	14	14	14
χ^2	24.79		2.28		3.89	
p	.001		.70		.05	

Ten of the 14 restricted dogs made responses which were classified as *diffuse emotional excitement*. They moved excitedly and rapidly near and around *E*, with short, jerky, to-and-fro movements. Whenever they tried to lick or "nuzzle" any part of *E*'s body, however, they assumed a characteristic bodily posture: the front part of the dog's body lay close to the floor, with the neck, head and forelegs stretched far forward; the hindquarters were at walking height, with the hind legs pushed back slightly, so that the dogs always appeared to be in a "springing" or "stalking" position. Rudimentary forms of friendly behaviour, avoidance, and aggressive stalking could sometimes be discerned in their profoundly excited behaviour, but its most striking feature was that no consistent, organized, adient social responses to the "friendly man" ever emerged from it. Any attempt by *E* to pat or touch the dogs produced only jerky withdrawal movements with a marked concomitant increase in excitement. This tended to be followed by rapid, circular, prancing motions, until they resumed their excited licking behaviour, usually in the characteristic "stalking" stance.

One normally reared and four restricted dogs showed *avoidance* of the "friendly man"; they continually withdrew from *E* and always maintained a distance of at least two feet between *E* and themselves. These differences in behaviour between the restricted and the free-environment dogs are significant at the .001 level.

(2) *Behaviour to the "timid man."* Of the 14 dogs in each group, 8 restricted and 9 normally reared dogs displayed a type of behaviour which appears closely related to diffuse emotional excitement, but is much better described as *aggressive stalking*. These dogs moved excitedly and rapidly to and fro in the characteristic "stalking" position, making short, jerky jumps, and constantly facing *E*. As the "timid man" retreated, however, this behaviour became a progressive, excited, forward approach, often with vigorous stamping movements of the forelegs in fitful starts and stops. And, as they moved nearer to *E*, they began to bark, growl, and snap their jaws with increasing frequency. However, the dogs rarely came within two feet of *E*.

This *aggressive stalking* gave the impression that the dogs were trying to "tease" a response out of *E*. They maintained the "stalking" posture almost continually in the presence of the "timid man," executing forward and backward movements with equal facility. Although they tended to spring forward toward *E*, they were also poised to spring backwards, and any sudden movement by *E*, even though in retreat, often elicited a sudden, short jump backwards by the dog.

The remaining responses to the "timid man" are shown in Table II. There is no statistical difference between the responses of the two groups of dogs, but, for the combined groups, the probability of such a high proportion of *aggressive stalking* occurring by chance in response to the "timid man" is .001 ($\chi^2 = 31.28$).

(3) *Behaviour to the "bold man."* The responses of the dogs to the "bold man" were classified as *avoidance* or *escape*. Of the 14 dogs in each group, 8 normally reared and 2 restricted dogs showed *avoidance*: they would usually stand quietly as the "bold man" approached, and then suddenly dash out of his way, never getting caught in a corner or against the wall. The remaining dogs (12 restricted, 6 free-environment) showed *escape behaviour*: they ran out of the way of the "bold man" only after they were nudged or pushed by his foot during his aggressive approach. Many of them got caught in corners or against the wall; others simply did not move and would have been stepped on by *E* had he not stopped. These differences between the two groups are significant at the .05 level of confidence.

(4) *Supplementary observations.* Seven restricted dogs, which had been reared two or three in a cage, were tested a year after their release along with four of their normally reared litter-mates. The restricted dogs still showed more diffuse emotional excitement to the "friendly man," and more escape behaviour to the "bold man," than did the free-environment dogs. But four restricted dogs showed friendly approach to the "friendly man," and two of them showed avoidance behaviour to the "bold man."

Thus there were no longer any statistical differences between the two groups in their behaviour toward these two roles.

Discussion

The outstanding feature of the behaviour of the restricted dogs in these tests was their obvious ineptitude in coping with the social situations presented to them. The dominance tests showed clearly that they were incapable of responding adequately in a competitive social situation with other dogs, confirming the earlier observations of Clarke *et al.* (**2**). Indeed, most of the restricted dogs appeared not even to know how to *try* to be dominant, thus putting themselves at the very bottom of the dominance hierarchy in their canine society. They also differed markedly from the control animals in their capacity to perform responses which would be instrumental in satisfying such a basic need as curiosity toward other dogs. They showed a general excitement in the presence of other dogs, but did not exhibit sustained, well-oriented curiosity toward them.

A similar lack of adequate social behaviour was observed in the responses of the restricted dogs to the three roles portrayed by the experimenter. They did not know how to accept and reciprocate the friendly approaches of the "friendly man." Nor were they able, in the threatening social situation presented by the "bold man," to avoid physical contact in the unexcited, organized manner typical of the normally reared dogs. After a year of living in a normal environment, however, there was a decrease in the high level of emotional excitement which characterized their earlier responses, and several of them exhibited friendly behaviour to the "friendly man" and avoidance of the "bold man."

It may be concluded, then, that restriction of early social and perceptual experience has a definite retarding effect on the emergence of normal, adult social behaviour in dogs, whether toward members of their own or other species. With opportunities to gain such experience, however, dogs reared in moderate isolation, at least, can overcome to a significant degree the adverse effects of restriction on their social responses to man.

Summary

Twenty-one Scottish terriers were raised for the first seven to ten months of life with their social and perceptual experience restricted in varying degrees. Their 16 litter-mates, serving as normal controls, were raised as pets in homes or in the laboratory.

After the restricted dogs were released, all dogs were given a series of tests of social behaviour. Tests for dominance showed that the restricted dogs were strikingly inept in a competitive situation, as compared with

the high degree of dominance behaviour displayed by the normal controls. Similarly, the restricted dogs did not exhibit the sustained, well-oriented curiosity toward other dogs that was observed in the control dogs. The restricted dogs were also unable to accept and reciprocate the friendly approaches of a "friendly man," or avoid physical contact with a "bold man" in the unexcited, well-organized manner typical of the normally reared dogs.

It was concluded that restriction of early social and perceptual experience has a definite retarding effect on the emergence of normal, adult social behaviour in dogs.

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PROBLEM-SEEKING BEHAVIOUR IN RATS[1]

JAROSLAV HAVELKA
McGill University

MAHUT (9) and Hebb and Mahut (7) have shown that when a rat is offered two routes to food, one direct, short, without complications, and the other less direct, longer, and with alternative routes (blind alleys), the animal has a marked tendency to take the more difficult route to food. The behaviour seems quite analogous to problem-solving for its own sake, as demonstrated in the monkey by Harlow and his colleagues (3, 4, 5, 6, 10). It is also related to a number of studies showing that exploratory and investigatory motivation are independent of the classical hunger, pain, and sex drives (1, 2, 8, 11, 12, 13, 14, 15, 16).

The purpose of the present study was to determine a means of quantifying the problem-seeking tendency in the rat, and to relate it to other behavioural variables.

METHOD

Fifty-five naïve hooded rats of the Royal Victoria Hospital Colony, 90 to 110 days of age, were used as subjects. Five animals were later discarded because they failed to move away from the starting box and to reach the food.

Two boxes were designed to measure the rats' tendency to seek a variable goal. Each of them contained a "fixed goal" and a "variable goal" (Figure 1). Box 1 had a plywood floor and walls, painted flat grey, and was covered with a wire screen. At either end of the box a cross-shaped barrier was located, also painted flat grey. The fixed goal was a food tray with wet mash located in a fixed position within one of the angles of one barrier. The variable goal was a similar food tray, but randomly moved after each choice-trial from angle to angle about the other barrier. The animal was placed in the starting box and permitted to go to either food goal and eat for five seconds. It was then replaced in the starting box for the next trial. Because Box 1 may have evoked left-going or right-going tendencies, a second box was designed in which the relationship between the two goals was near-far instead of left-right (Figure 1, Box 2). In all other respects it was like Box 1, except that the fixed goal was always near the starting box, making the variable goal clearly the longer route to food.

In the first situation rats were given 20 days of training, the first 10 of which were simply to accustom the animals to the 24-hour feeding schedule. On each of days 11 to 14, the rats were placed in Box 1 for two 20-minute periods daily while hungry. No food was available in the box. On each of days 15 to 18 the rats were

[1]This paper is based on portions of an M.Sc. thesis submitted to McGill University in 1954. The writer is grateful to Professor D. O. Hebb and Dr. H. Beach for many helpful criticisms and suggestions.

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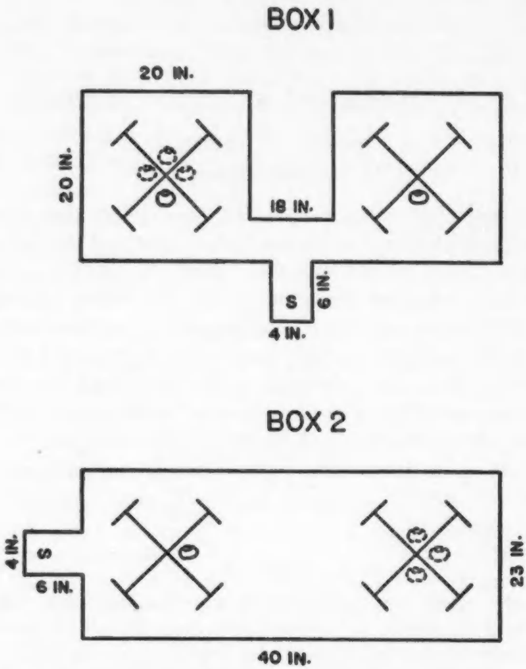

FIGURE 1. Ground plan of problem boxes 1 and 2 showing cross-barriers.

given 10 free-choice trials daily, and on days 19 and 20 they were forced to alternate, right and left. The food was fixed within one of the four angles of each of the cross-shaped barriers and the location was kept constant from trial to trial.

On the 21st day the animals were introduced to the first test situation (Box 1). For one half of the animals food was located in a fixed position within one angle of the right cross-barrier with the variable goal on the left. For the other half of the subjects the variable goal was on the right. The rats were given 10 consecutive choice-trials daily for eight days, choosing between the fixed goal and the variable goal. Immediately after each test session the animals were fed wet mash *ad libitum* on a feeding stand.

The next day (day 29) the same animals were introduced to the second test situation (Box 2). In order to habituate them to the new box, animals were allowed to explore it for 20 minutes, in groups of five, on 10 successive days (days 29–38). This procedure gave the animals training in "looking for" food at the variable goal, a feature which was not controlled in Box 1. During this adaptation period food was placed in a fixed location within the near barrier, and was varied in location around the far barrier (the variable or problem goal). On each of days 39 to 46 the animals were given 10 consecutive choice-trials daily. Finally, in order to isolate the effect

of variability in the far goal, on each of days 47 to 54 the rats were given 10 consecutive choice-trials daily with the food fixed within one angle of *both* cross-barriers of problem box 2.

Results

In the first test, the 50 animals could be divided into 3 groups whose mean choices of the variable goal nowhere overlapped. Eighteen rats (Group A) clearly preferred the variable goal, 16 (Group B) the fixed goal, and 16 (Group C) showed no preference, making about the same number of choices of each goal. The animals' choices were highly reliable: the product-moment correlation coefficient between the first 30 and last 30 choices for all animals was 0.80 ($p = .001$). It is evident that each

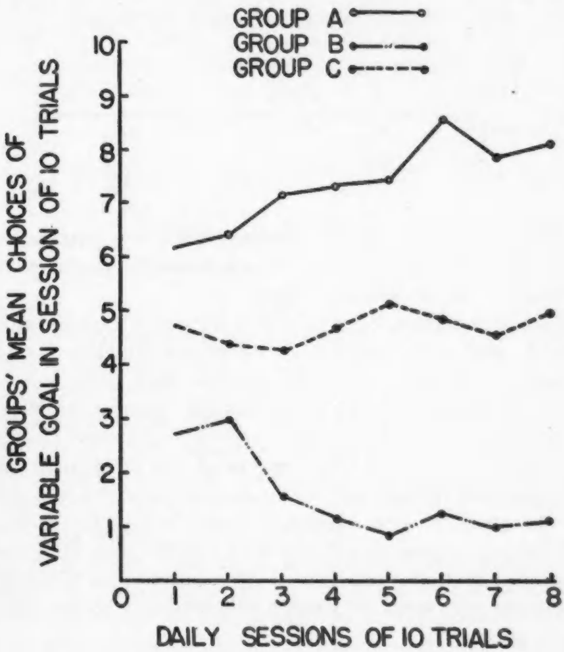

FIGURE 2. Rats' choices of variable goal on Problem 1.

group's preference tendency was manifested from the beginning (Figure 2). Moreover, the initial tendency of Groups A and B increased throughout the eight sessions of trials to the point where Group A was choosing the variable goal about 83 per cent of the time in the last 30 choices,

while Group B was choosing the fixed goal about 90 per cent of the time. Group A's increase is significant ($t = 6.57$, $p = .001$) as measured by the difference between mean goal choices in the last four sessions and the first four; Group B's decrease is also significant ($t = 5.89$, $p = .001$).

The group differences observed in problem 1 were maintained for problem 2 (Table I) although, in the latter case, choice of the variable goal involved by-passing the food in the fixed goal and travelling about three times as far. Once again the rats' choices of the problem goal were highly consistent between the first and last 30 trials ($r = .80$, $p = .001$). These data leave no doubt that the rats exhibited typically different behaviour tendencies with reference to a variable goal situation.

TABLE I

MEAN CHOICES OF VARIABLE GOAL (80 TRIALS) IN PROBLEM BOXES 1 AND 2

Group	N	Probl. Box 1	Probl. Box 2
A	18	59.7	59.8
B	16	12.5	10.3
C	16	36.9	36.5

On problem 2, again, each group's preference was manifested in the first session of the choice trials and the preferences of groups A and B increased over the eight sessions (Figure 3a).

In order to isolate the influence of the changing location of the food in the variable goal on problem 2, an additional 80 trials were given in problem box 2 with the food *fixed* in both goals. This resulted in a general shift of choices by all rats to the goal nearer the starting box. Group A exhibited the most dramatic change, and even Group C rats (those alternating) increased their choices of the short route. However, the remote food goal still attracted some animals, and still to a differential degree by groups as follows: Group C more than Group B ($t = 5.69$, $p = .001$), Group A more than Group B ($t = 3.50$, $p = .01$), and Group C more than Group A ($t = 2.44$, $p = .05$). It was now Group C which chose the remote goal most frequently, this tendency being extinguished rather slowly (Figure 3b).

DISCUSSION

The rats in this study exhibited three distinct types of response to the variable goal situation, and were consistent in their choices of response: Group A preferred the variable goal even when it involved the longer route; Group B preferred the stable goal and short route, and Group C chose the two goals almost equally.

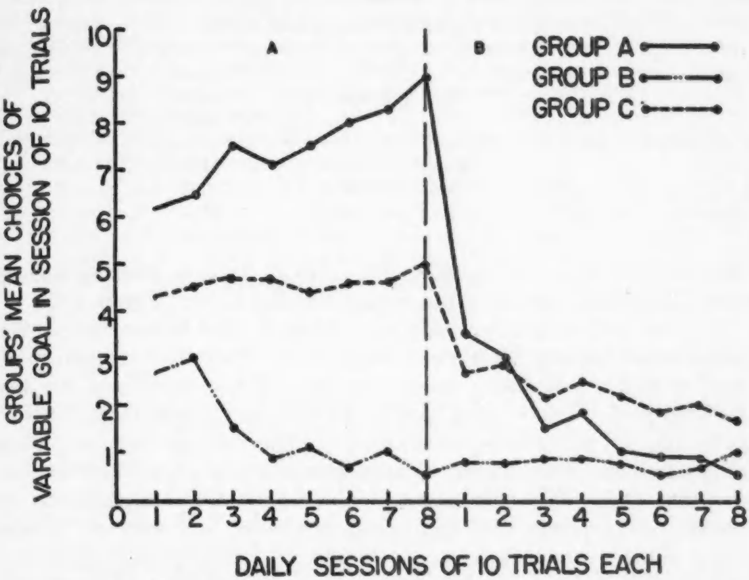

FIGURE 3. Rats' choices of variable goal on Problem 2.

Group B's behaviour is consistent with the Hullian theory of learning, but Group A's behaviour, and to some extent Group C's, are in conflict with Hull's predictions. The behaviour of the latter groups was apparently a function both of hunger drive and of an external factor, the changing location of the food. No immediate interpretation can be offered for the individual differences in preference. The three groups did not differ significantly in age, weight, sex, or in intelligence as measured by the Rabinovitch-Rosvold closed-field test (18).

The problem-seeking behaviour exhibited by Groups A and C is distinguishable from exploratory behaviour. Exploratory behaviour appears to depend on perceptual arousal evoked by novel stimuli. As the organism becomes adapted to these stimuli, however, exploration diminishes and finally terminates. Problem-seeking behaviour, also dependent on perception, is aroused by a continually varying relationship between barriers and food goal. The organism does not become adapted to such a changing pattern but seeks progressively more commerce with it. Only when the factor of "unpredictability" was withdrawn, by fixing the location of the food within what had been the variable goal, did the problem-seeking

TABLE II

MEAN CHOICES OF THE REMOTE GOAL

Group	N	Problem 2	"Variable" position fixed
A	18	59.8	14.0
B	16	10.3	5.5
C	16	36.5	20.0

rats cease to go to the variable goal position. That is, problem-seeking terminates with removal of the unpredictability factor (Figure 3b).

In addition to unpredictability, a number of other factors such as the presence of barriers, delay in attainment of food, and complexity of environmental stimulation may contribute to the preference for the variable goal. The changing location of food may constitute a "barrier" in that the rat must exert greater effort to attain food. Barriers have been shown to increase the valence or attraction of a goal (8). With reference to delay, Olds (17), elaborating Hebb's theory of the organization of behaviour, proposed that such delay increases "the intrinsic reward value of the secondary reinforcing stimulus, S^r," and reported supporting evidence. Since having to locate the food in the variable goal necessarily involves delay in attaining it, the delay factor may play a part in augmenting the reward value of the problem goal. The complexity of environmental stimulation may also affect problem-seeking behaviour, and could be made an independent variable in future research.

SUMMARY

Fifty hungry rats were offered two alternative routes to food, one short and direct, the other posing a problem in that the food had to be searched for. In one experiment the problem route also required a longer run.

Animals were found to differ in their choice of routes, and to be highly consistent in their choices. About one-third of the rats showed a marked problem-seeking tendency, clearly distinguishable from exploratory behaviour. These differences were not related to intelligence.

The findings are discussed in terms of the motivational properties of perception.

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SOME INVARIANT PROPERTIES OF BEHAVIOUR AND THE PROBLEM OF METRICS FOR SOCIAL RELATIONS

VLADMIR CERVIN
University of Toronto

THIS NOTE is concerned with the methodology for dealing with such problems as stress tolerance of personality or groups, response to psychotherapy, group boundaries, group cohesion, and so on. These problems may be formulated in terms of "association" of one or more independent variables (e.g. stimulus) which vary within certain ranges, on the one hand, and a dependent variable (e.g. response) which remains unchanged up to a certain limit (threshold) of variation in the independent variable, and only then begins to vary, on the other. For example, a patient does not respond to treatment up to a certain point, then begins to improve. The opposite case is also frequent, namely, when the dependent variable varies up to a certain limit of variation of the independent variable, then stops varying. For example, a person may perform his duties normally under stress, but if stress reaches a certain limit, may "break down."

In such cases we want to know at what value (or range of values) of the independent variable the dependent variable is likely to begin (or stop) varying. This is the problem of "limits of invariance"[1] of the dependent variable with respect to the independent variable. We are not concerned here with the case of no variation at all, i.e. independence.

If variation of the independent variable can be measured quantitatively (e.g. concentration of a poison, intensity of a physical stimulus), the problem can be handled by probit analysis (3, 4, 8), which is based on the distribution of tolerance thresholds over a certain population (dependent variable) associated with the variation of a given independent variable. Probit analysis can be used to study such problems as: what percentage of individuals will break down under a given intensity of stress (group morale may ultimately find its operational definition in terms of probits); what percentage of patients will respond favourably to treatment of a given length; what is the relative potency of two or more psychotherapeutic treatments; what are the tolerance regions of varying amounts of stress; or, vice versa, what is the amount of "response" to a given change in intensity of stress agent.

[1]As used here, this concept is akin to that of "dynamic equilibrium" in systems theory.

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However, the independent variable is not always measured quantitatively but appears as a set of qualitatively different stimuli (e.g., in most social situations). In this case some kind of metric must be found for it. This problem may perhaps be attacked first by Guttman's scale analysis (5). Attitudes have been scaled in this way (5, 6), and at Toronto we have established Guttman scales for two personality dimensions (to be published). Or it may be attacked directly by "analysis of invariance" in behaviour (1).

The search for invariants involves establishing isomorphism between certain mathematical groups of transformation and conditions under which certain properties of behaviour remain unchanged (1). The notion of mathematical groups and invariants is aptly discussed by Stevens (7). One group of transformations, of great importance for the psychology of social groups, is that of permutations (7). Problems of group boundaries (2), or of establishing who should and who should not be counted as a member of a group (especially if the group is unorganized), can be formulated in terms of groups of permutations. For example, a company of soldiers in combat can be represented as a group of permutations of n "objects." The fighting men constitute the "objects"; substitution of certain men for others, which does not change the company's resistance to the enemy (invariant relation) constitutes the "operations," i.e. elements of the group of permutations; a man returning to the front from hospital to occupy his former position constitutes the identical operation; if he relieves a man who had previously replaced him, we have the inverse operation. The rule of combining the operations is simply performing them in some order. Applied in this way, the concept of the group of permutations serves a much more useful purpose than mere classification or labelling of men. The difference is due to the choice of the invariant—a social relation (resistance to the enemy) which is preserved intact under the group of substitutions of group members by one another. Given a particular goal and a number of individuals, one can determine, with the help of the concept of group of permutations, who should be in a group (2); selecting a relation to the goal as the invariant, one can test the individuals to see who among them satisfies this condition. Those who do are potential members. This is merely a formal statement of what people actually do in real life situations. Conversely, one may want to determine what relations constitute an invariant in a given group. Testing all group members, one may discover that there is more than one invariant. Some invariants, however, may apply only to certain members, not to others. On this basis one can determine which members constitute subgroups (cliques) within a group. Problems of psychotherapy, resistance to stress, etc., can be similarly conceptualized in terms of mathe-

matical groups. The "analysis of invariance" approach should be particularly fruitful in the study of "normal" behaviour.

Formulation of certain psychological problems in terms of mathematical groups and invariants not only serves the purpose of rigour and clarity, but also has a methodological significance. Establishment of groups of permutations among members of social groups is the first step toward identifying group dimensions and finding metrics for them. Thus, separating members from non-members, which satisfies certain conditions of invariance, amounts to dichotomous scaling. One may proceed further and, taking only members, establish a rank-order among them (e.g. according to the amount of work each one performs to attain the group goal). To insure unidimensionality of rank-ordering, at least two invariants should be preserved under different conditions: relation to the group goal and the position of each member with respect to his neighbours. Therefore rank-ordering itself must preserve unchanged the basic relation of members to the goal.

Analysis of invariance, as suggested in this note, should lead to the identification of unidimensional continua in the field of social behaviour, and help in the construction of appropriate metrics. It also lies at the basis of every generalization.

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PSYCHOLOGICAL STRUCTURE AS THE GOVERNING PRINCIPLE OF PROJECTIVE TECHNIQUE: RORSCHACH THEORY[1]

HERBERT DÖRKEN, JR.[2]
Verdun Protestant Hospital, Montreal

CONCERN for the development of a parallel set to the Rorschach (**4, 8, 15**) or for "improvement" of the test material through varying the stimulus properties (**11**), and criticism of studies employing the split-half technique (**10, 13, 18**), all neglect one cardinal fact: that the consistency of the subject in responding to varied stimulus material is more basic to the projective technique than the employment of standardized test material. The strength of the individual's characteristic mode of perception, whether he is normal or mentally disordered, permits a surprising degree of variance in the formal aspects of the test material before response is significantly altered (**1, 6, 13**). Similarly, attempts to delineate the specific properties of the Rorschach test material, and efforts to standardize it, have tended to divert attention from the dominant role of personality, on which the validity of projective tests depends.

Brosin and Fromm state that a considerable amount of variation in the field "will still elicit similar responses [since there is] a wide range of possibility for recognition of similar configurations" (**3**, pp. 5, 6). And Frank says:

> Since the individual strives to maintain his personal version against the coercion or obstruction of others, it is evident that personality is a persistent way of living and feeling that, despite change of tools, implements, and organic growth and maturation, will appear continuously and true to pattern. . . . If it appears that the subject projects similar *patterns* or *configurations* upon widely different materials . . . then the procedures may be judged sufficiently valid. . . . [**9**, pp. 404, 409].

Studies of the dynamic basis of form (**2**, p. 254) make it clear that strong form depends more upon the dynamic properties of the organism than upon properties of the stimulus, and hence there is no necessary correspondence between the form of the stimulus and the form of the perception. The stimulus must always have a personal meaning, no matter how controlled or objective, and thus is never an absolute standard. It

[1]Past-Presidential Address, Annual Meeting, Psychological Association of the Province of Quebec, Montreal, May, 1956.

[2]Thanks are extended to Dr. George E. Reed, Medical Superintendent, for his cooperation and kind permission to publish this paper.

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is this stimulus fallacy, first described by Thurstone (**16**), which is exploited in the projective technique; personal values become selective factors in perception. The varied qualities of a stimulus cease to be a disadvantage (as in objective tests) and become of crucial importance for they invite the expression of personal values.

Confirming Investigations

Utilizing the split-test (odd-even) method of correlation, Hertz (**10**) has shown that response determinants, their location, and at times their content, are significantly consistent when related, but not identical, stimuli (test material) are used. She reports an average coefficient of correlation of .829 (range .66 to .97) for 20 Rorschach categories. Similarly, the number of responses to the test was shown to be reliable (average correlation .853) for the three groups studied by Wirt and McReynolds (**18**). Orange (**13**) employed two matched groups in his split-test (odd-even and ambiguous-structured) rank order analysis, and found that for both groups the number of correlations significant of consistency among 11 categories in each type of split-half was far better than chance. He concluded:

> Contrary to the contention of Rosenzweig (1951) and Sargent (1948) that the factor of differential stimulus-import on the Rorschach renders employment of split-half techniques theoretically impracticable, the establishment of extensive reliabilities in this study precipitates the challenging conclusion that organizational functions in perceptual behavior are self-assertive despite changing stimulus-configurations [**13**, p. 228].

Another approach to the problem is provided by studies comparing performance on the Rorschach and Behn-Rorschach inkblots. While the authors (**4, 8, 15**) are concerned with the evaluation of a "parallel" set, their findings may be construed rather as supporting evidence for a rationale which considers the consistency of the subject, rather than standardization of test material, as the principal control in projective technique. Indeed, the necessity of developing a parallel set can be seriously questioned (**5, 6**). Buckle and Holt (**4**) have shown that these two sets of inkblots yield very similar total profiles: "The resulting similarity is not only one of similarity in scoring category, but is often a complete identity between actual responses given to the two blots" (p. 491). Singer's matching studies show "that the kind of response elicited by inkblots and extrapolated to everyday living is fairly stable despite objective differences in the blot series" (**15**, p. 244). The "group profile on the Behn would be almost identical with that on the Rorschach . . . the two tests seemed in this study to elicit in general the same number and type of responses" (p. 241). Eichler's study (**8**) clearly demonstrates the reliability of the

inkblot test method. On retesting three separate groups within a median interval of 21 days (Behn vs. Rorschach, Rorschach vs. Behn, Rorschach vs. Rorschach) he found that: "In general, the Behn showed substantial agreement with the measures obtained by the standard Rorschach, with reliabilities for Groups I and II comparing favorably, for the most part, with those obtained under the Rorschach test-retest condition. All coefficients were significant at the 1 per cent level" (p. 187). For the 12 scoring categories compared, the reliability coefficients ranged from .43 to .85 (average .648) for the Behn vs. Rorschach comparison, and from .46 to .67 (average .562) for the Rorschach vs. Behn comparison. "Consistent repetition effects under all three conditions were manifested by the changes in . . . [four] categories" (8, p. 187).

On the other hand, Wells (17), among others, claims that what will be seen is, to an appreciable extent, a function of the manner in which the figures are made. Discussing the influence of the formal design of the stimulus on the Rorschach response, he notes that symmetrical figures made with little or no white space on a vertical fold predispose to whole responses of an anthropoid or non-reptilian vertebra, while symmetrical figures having considerable white space about a vertical fold predispose to whole responses of two creatures reacting to each other. That the unique formal design of each inkblot (stimulus value) has some influence on response is evident from the existence of particular popular or common responses to the different Rorschach plates, and from minor variations of response between the Behn and Rorschach series (4, 8, 15) and between the chromatic, achromatic, and non-shaded versions of the test (1). This influence, however, must be relatively less than that of the individual personality structure, otherwise there would be insufficient divergence of response between individuals to provide any basis for the differential evaluation of personality. Indeed, the method can actually be varied to the extent of allowing each subject to manufacture his own inkblot. Even under this extreme lack of standardization in the test material, Ink Blot Test results are consistent with Rorschach findings (6).

McFarland (12), who was concerned with the development of several variables which would be consistent throughout a series of different tests, found his subjects' responses to inkblots, pictures, and small concrete objects tended to be consistent, both quantitatively and in terms of the relative range of percepts responded to. More interesting in the present context are his undiscussed results, which show that the modified Rorschach and modified Behn-Rorschach correlate significantly with one another on all six variables considered (range .68 to .29, average .53).

The most convincing demonstration is the recent investigation of Baughman, who concludes: "Many of the measures that we make of

perceptual behavior in the Rorschach test appear to be primarily dependent upon processes inherent in the perceiver . . . rather than upon properties of the stimulus" (1, p. 163). He devised four experimental series of designs in addition to the standard Rorschach series. The identical peripheral form was maintained in each, but within this limitation one or more of the attributes of colour, shading, figure-ground contrast, and internal form were varied. One series was individually administered to each of five neurotic groups. The author states:

> The data are clear and impressive in their demonstration that the major dimensions of perceptual behavior in the Rorschach task remain remarkably constant even though marked alterations are made in the stimulus attributes. In twenty-one of the thirty-nine scoring categories no group differences occurred at or above the .05 level of significance. Moreover, all of the differences . . . which are significant at the .01 level can be explained on the basis of diminished availability of a particular stimulus attribute in one of the series being compared. . . . The fact that perceptual behavior is so minimally affected by major changes in stimulus characteristics should make us feel more secure in our use of such techniques for personality evaluation. The fact that we affect behavior so little by changes in the external conditions points up the extent to which such behavior is determined by personal characteristics of the individuals [1, pp. 161, 163].

Comments

Behn-Eschenburg, Harrower, and Howard have developed sets designed to be, respectively, equivalent to, complementary to, and more provocative than, the Rorschach. However, it appears that they are probably comparable, and that there is no basis on which to expect any one of them to elicit responses significantly different from those made to others. This view calls seriously into question the "advantages" of varying the shading and colour characteristics, for example (**11**), and the need for a "parallel" set (**1, 6**).

The results of the studies reviewed here (especially **1, 6, 8, 13, 18**) are highly encouraging, and permit a more favourable view of the reliability (through retest, split-half, modified series, and group stability methods) of the Rorschach test than was possible seven years ago (**14**). While one would expect results to be most consistent (reliable) among subjects with mental disorder, and probably in proportion to the severity of their illness, this question does not yet appear to have been sufficiently studied. However, the more typical a subject is of a specific psychiatric disorder (especially in the chronic stages) the more circumscribed and "typical" (statistically reliable) will his response become.

Another point worth noting is that, while response remains remarkably consistent in the face of marked alterations of *degree* in the stimulus material, this is no reason to assume that results from different *types* of

projective tests will also be consistent. There is some evidence that different types of projective tests may yield results which are not necessarily interrelated (7). Indeed, the possibility that each type of projective technique may offer results which are consistent in themselves and yet unrelated to the results from other types of projective techniques, and that the extent of this disparity may reflect the degree of internal change within the personality structure due to mental disorder (7), opens a fascinating new approach to the study of the organization of personality.

Conclusion

The remarkable consistency (similarity) of response which subjects display to a wide variety of inkblots makes it evident that the psychological structure of the individual is the governing principle of his projections, and that these are but minimally dependent on the formal characteristics of the projective (Rorschach type) test material.

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A NON-DUPLICATING CIRCUIT FOR SWITCHING COUNTER SIGNALS[1]

LEONARD GELFAND
Department of Psychiatry, University of Toronto

STUDIES employing counting measures of performance frequently require a record for consecutive short segments of a total continuous performance period. When only one magnetic counter is used, a reading can be taken at fixed time intervals. When several measures are recorded simultaneously, however, it is impossible to read all the counters instantaneously. A record can then be obtained by employing two banks of counters and automatically switching the signals from one bank to the other. Thus the experimenter can read the inactive counters while the others continue to record.

However, a problem arises if the switchover from one bank to the other occurs while a signal is being fed to any of the counters. The signal has already activated one counter, and when switched over will

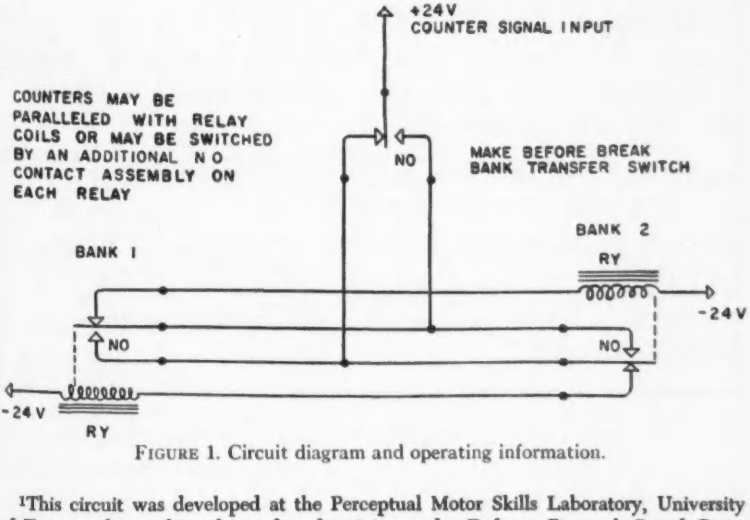

FIGURE 1. Circuit diagram and operating information.

[1]This circuit was developed at the Perceptual Motor Skills Laboratory, University of Toronto, for studies of transfer of training under Defence Research Board Grant No. 265.

CANAD. J. PSYCHOL., 1956, 10 (2).

activate another counter. As a result, two counts will be obtained where only one count should register.

The double count can be eliminated by means of the simple circuit shown in Figure 1. If a signal which is fed through this circuit has operated a counter and is still present when the switchover to another counter occurs, it will not register on the other counter. For all other conditions the circuit functions as a simple transfer switch.

AN AUTOMATIC SWITCH WITH VARIABLE "OFF" AND "ON" INTERVALS[1]

LEONARD GELFAND
Department of Psychiatry, University of Toronto

AND R. SPENCER SOANES
Canadian Research Institute, Toronto

THIS SWITCH was developed for automatically controlling the length of rest, practice, and total session times in studies of human motor performance. It functions as a simple off-on switch to start and stop the apparatus. The duration of the "off" or rest period, the duration of the "on" or practice period, and the total number of off-on cycles presented during any experimental session can be quickly and independently varied by throwing several toggle switches and setting four knobs. Pressing a button starts the switch, which first presents the subject with a ready signal, then turns on the apparatus for the pre-set time, and then turns it off, again for the pre-set time. This sequence is automatically repeated for a pre-set number of cycles.

Design of the switch was prompted by two limitations present in the standard devices employed to control time intervals: the lack of accuracy for long time intervals characteristic of electronic switches, and the difficulty of changing the time intervals rapidly when mechanical switches are employed. This device combines the accuracy of mechanical timers with the rapidly variable time intervals of electronic timers. The present model has the following characteristics:

1. Length of the "on" or practice period is adjustable from 20 seconds to 12 hours and 32 minutes, in 20-second steps. However, "off" or rest periods cannot be interpolated between "on" periods which are longer than 15 minutes and 40 seconds.

2. Length of the "off" or rest period is adjustable from 5 seconds to 3 minutes and 55 seconds, in 5-second steps.

3. An automatic ready signal occurs for 5 seconds before the beginning of any "on" period.

4. Provision is made for automatically switching signals from one set of clocks and counters to another at 20-second points timed from the beginning of any "on" period.

[1]This circuit was developed at the Perceptual Motor Skills Laboratory, University of Toronto, for studies of transfer of training under Defence Research Board Grant No. 265.

5. The timing error of any 20-second "on" interval and any 5-second "off" interval is less than ± 0.01 seconds, as measured by a model S.1 Standard Electric Timer.

Operating Principle

The switch is divided into three sections, one controlling the "on" period, a second controlling the "off" period, and a third controlling the total number of "on-off" sequences. The "on" and "off" sections are each made up of a device which produces electrical pulses at fixed time intervals and a device which counts these pulses. Thus the total "on" and "off" periods must be some multiple of the fixed pulse intervals. The pulses are produced by two microswitches operated by two cams coupled to a common continuously running synchronous motor through magnetic clutches. Multibank stepping switches serve as counters and perform other necessary functions. The total-cycles section is simply a stepping switch operating as a counter. All sections of the switch are powered by a 24-volt D.C. supply.

After the motor and power supply are activated, the switch is started by pressing the start button. This "homes" the total-cycles counter, energizing the entire switch circuit. The "off" counter now activates its magnetic clutch, starting the "off" cam and beginning the timing of the "off" period. The rotation of the "off" cam operates the associated microswitch which sends pulses to the "off" counter. When the "off" counter has received one pulse less than the number for which it has been set it starts the ready signal.

Upon receiving the next pulse, the "off" counter ends the "off" period by simultaneously switching on the apparatus, stopping the ready signal, deactivating its magnetic clutch, and starting the "on" counter. The "off" counter then "homes."

The "on" period is now timed in a similar manner by the "on" counter with its associated clutch, cam, and microswitch. When the "on" counter has received the pre-set number of pulses it starts the "off" counter, which turns off the controlled apparatus, thus ending the "on" period and beginning the "off" period. The "on" counter also stops its cam, transmits one pulse to the total-cycles counter simultaneously with the starting of the "off" counter, and then "homes."

The cycle now repeats until the total-cycles counter has received its pre-set number of pulses. At this time the switch stops, and may be pre-set for different periods or immediately started again for the previous conditions.

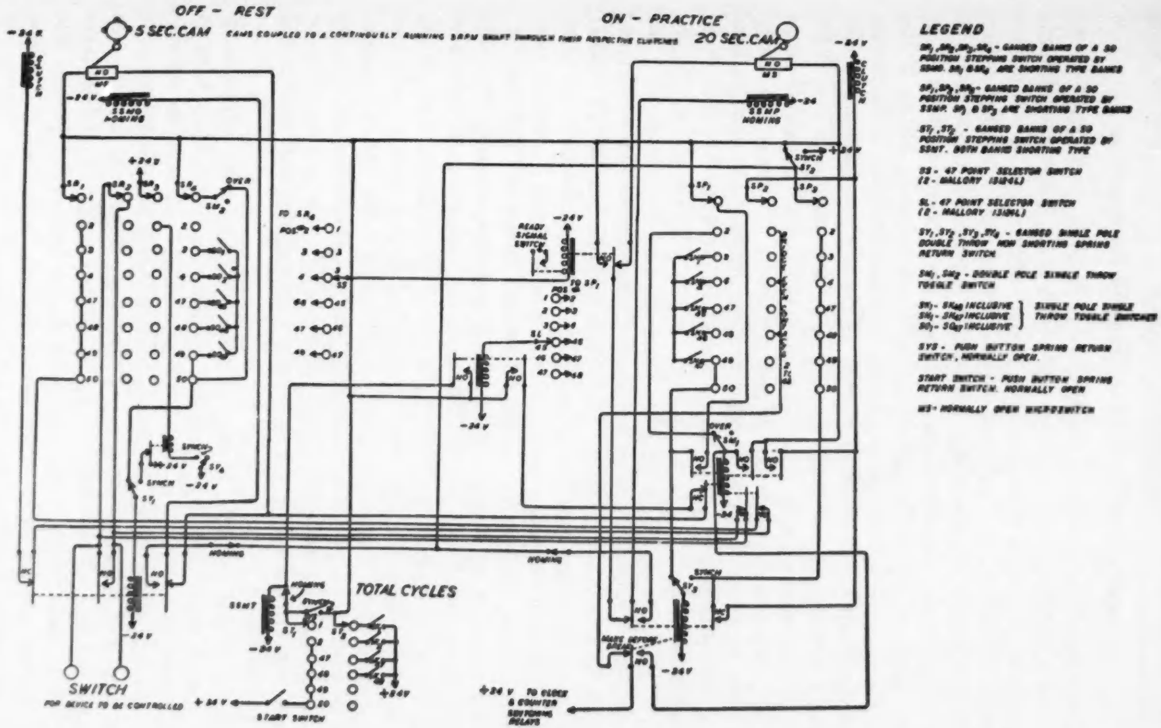
OFF - REST
5 SEC.CAM
CAMS COUPLED TO A CONTINUOUSLY RUNNING 3RPM SHAFT THROUGH THEIR RESPECTIVE CLUTCHES
ON - PRACTICE
20 SEC.CAM
SSMO HOMING
SSMP HOMING
READY SIGNAL SWITCH
TOTAL CYCLES
SSMT
SWITCH
FOR DEVICE TO BE CONTROLLED
START SWITCH
+24 V TO CLOCK & COUNTER SWITCHING RELAYS
MAKE BEFORE BREAK
LEGEND
SR1, SR2, SR3, SR4 - GANGED BANKS OF A 50 POSITION STEPPING SWITCH OPERATED BY SSMO. SR1 & SR4 ARE SHORTING TYPE BANKS
SP1, SP2, SP3 - GANGED BANKS OF A 50 POSITION STEPPING SWITCH OPERATED BY SSMP. SP1 & SP3 ARE SHORTING TYPE BANKS
ST1, ST2 - GANGED BANKS OF A 50 POSITION STEPPING SWITCH OPERATED BY SSMT. BOTH BANKS SHORTING TYPE
SS - 47 POINT SELECTOR SWITCH (2 - MALLORY 1312AL)
SL - 47 POINT SELECTOR SWITCH (2 - MALLORY 1312AL)
SY1, SY2, SY3, SY4 - GANGED SINGLE POLE DOUBLE THROW NON SHORTING SPRING RETURN SWITCH
SM1, SM2 - DOUBLE POLE SINGLE THROW TOGGLE SWITCH
SR1 - SR48 INCLUSIVE
SN1 - SN47 INCLUSIVE
SQ1 - SQ47 INCLUSIVE
SINGLE POLE SINGLE THROW TOGGLE SWITCHES
SYS - PUSH BUTTON SPRING RETURN SWITCH, NORMALLY OPEN.
START SWITCH - PUSH BUTTON SPRING RETURN SWITCH. NORMALLY OPEN
MS - NORMALLY OPEN MICROSWITCH

FIGURE 1

Circuit Description and Operating Information

The circuit diagram of the automatic switch is shown in Figure 1. It will be observed that the "on" and "off" counters are basically multibank 50-position stepping switches, which "home" after reaching the pre-set position. The total-cycles stepping switch "homes" when the start switch is closed. This automatic switch will not start properly unless SR is in position 2, SP is in position 1, and ST is in some position where SK is open. These or equivalent conditions will automatically obtain if the switch has completed any pre-set series of cycles. However, if the switch is stopped before it completes its series, all the stepping switches can be brought to their proper starting positions by first closing SYS until ST stops, and then moving SY to the "Synch" position until SR and SP stop. ST will not normally be in the correct position if the total-cycle setting has been increased from a previous setting. Hence SYS must be kept closed and the switch power supply must be on while the total-cycle setting is increased.

The procedure for pre-setting the timer can best be described by two illustrations. The first is a situation where S must practise for 40 seconds, rest for 20 seconds, and continue this cycle until he has had 20 minutes practice. This means that the switch must be pre-set for two "on" steps (each step is 20 seconds), four "off" steps (each step is 5 seconds), and 30 total cycles (each cycle permits 40 seconds' practice). The two "on" steps are pre-set by closing SN.2 to SN.47 inclusive, opening SN.1, and setting SL to the No. 2 position. The four "off" steps are set by closing SO.4 to SO.47 inclusive, opening SO.1 to SO.3 inclusive, and setting SS to the No. 4 position. Because a single "on" period is 40 seconds, and hence is less than 15 minutes 40 seconds, SM is set to the "under" position. The 30 total cycles are set by closing SK.1 to SK.30 inclusive, and opening SK.31 to SK.48 inclusive. The automatic switch is now pre-set. After the power supply and motor are energized, pressing the start button will start the sequence.

In the second example, S must practise for 20 minutes continuously. SM is now set to the "over" position, because the switch must have an "on" period greater than 15 minutes 40 seconds. It will be observed that 60 consecutive 20-second "on" intervals must be set into the switch. The "on" period is therefore pre-set at 30, because this is the largest even integer less than 47 by which 60 can be divided to obtain a whole number. This whole number, 2, is entered into the total-cycles section. The "off" period can be set to any desired interval, since the "off" section only determines the time between the pressing of the start button and the onset of the ready signal and "on" period when SM is at "over."

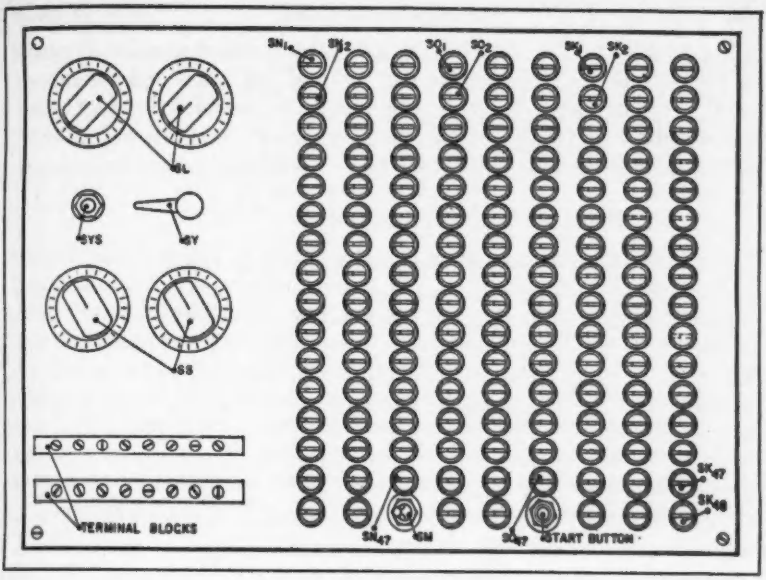

FIGURE 2. Front panel layout.

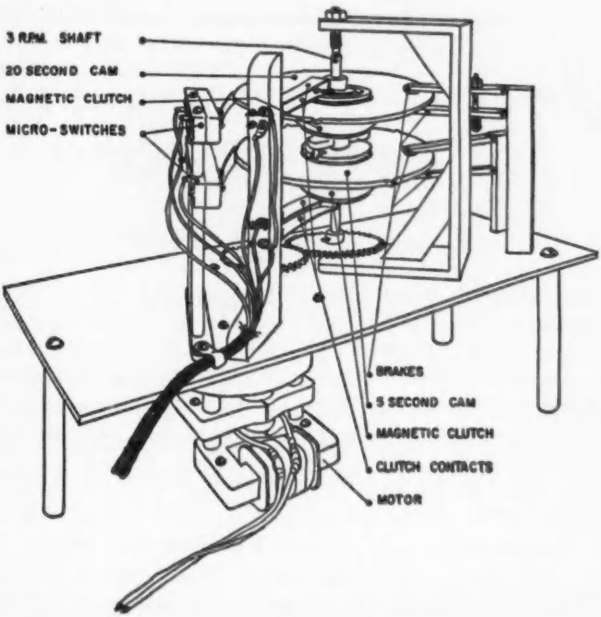

FIGURE 3. Cam details.

The length of the basic intervals, indicated in this discussion, depends on the number of protrusions on the "on" and "off" cams and the rate of rotation of the cams; hence it can readily be modified to meet other specifications. Stepping switches with a greater number of positions would increase the number of basic time intervals that could be counted.

Construction

The front panel of the present model is shown in Figure 2, and Figure 3 shows the cam details. Parts and layout are not critical matters, and any convenient construction procedure may be employed. Most components used in the present switch are available as surplus items, and total cost of the machine, including a 1-amp. 24-volt D.C. power supply, is approximately $130 exclusive of labour. Labour time is considerable, but no special care other than good soldering is required.

The cams must be cut accurately, because these determine the accuracy of basic time interval. In addition a light brake is required on each cam to prevent any turning when the magnetic clutch is not energized.

The Life and Work of Sigmund Freud: Volume 2: Years of Maturity, 1901–1919. By ERNEST JONES, M.D. London: The Hogarth Press (Toronto: Clarke, Irwin & Co. Ltd.), 1955. Pp. xviii, 534. $6.25.

If often he was wrong and at times absurd,
To us he is no more a person
Now but a whole climate of opinion. AUDEN

IN HIS second volume, the architectural advantages of Dr. Jones's monumental and definitive design become clearer. The material is grandly set forth in three leisurely divisions, entitled respectively, "Life," "Work," and "The Man." At first one rebels at the implication that these can in any true sense be separated; but with the reiterative cumulation of trait upon idea upon event, a more and more sculptural image emerges, and the somewhat abstract character summary which closes the volume seems in every detail supported by the rich concreteness of previous pages. A well chosen appendix of brief excerpts from important letters adds further depth and colour.

The emotional climax of the volume inevitably comes early, with the painful "Dissensions" of Chapter 5. Here a particularly interesting feature, for a reader on this continent, is the much greater scientific respectability with which the Jung of the period emerges from Jones's account, than does Adler. Intellectually, the clinically oriented reader will probably find the climax in the series of great case histories described in Chapter 11. Dr. Jones presents just enough detail to support his account of the development of Freud's theoretical and technical position, without blunting the appetite which he awakens for the originals. This chapter, together with Chapter 13 on "Contributions to Theory," conveys a genuine feeling of excitement; not by any specious novelty of interpretation, but by simple clarity and cohesiveness.

Concerning the personality of his subject, however, as distinct from events and theories, Dr. Jones's interpretations are perhaps open to more discussion. He is decidedly on the side of Eros and the angels, and admits unhesitatingly his wish to place Freud there also. Certainly he effectively demolishes, by numberless details of domestic, social, and intellectual warmth, the still prevalent myth of a paranoidal tyrant. Yet there remains the continuing preoccupation with bowel function, the recurring certainty of death by a certain date, the constant magnetic attraction towards the sepulchral stasis of Egypt and Rome, the correlative rejection of lively new phenomena such as America, the compulsive orderliness of times and persons and finances, and many other hints of similar import, clearly documented but so far not well interpreted in this work. A full account of Freud's self-analysis can never be given.

But in its absence it is difficult not to suspect the persistence of Thanatic, pre-genital motives; well compensated, for the most part, but never truly resolved, and possibly reaching somatic expression in the final torturing malignancy. One awaits impatiently the light which may be shed upon these and similar points by Volume 3 of this masterful work.

PAUL CHRISTIE

Queen's University

Psychology. By DELOS D. WICKENS and DONALD R. MEYER. Toronto: The Macmillan Co. of Canada, 1955. Pp. vi, 541. $5.50.

An Introduction to Psychology. By HARRY W. KARN and JOSEPH WEITZ. New York: Wiley (Toronto: Univer. of Toronto Press, 1955). Pp. xi, 315. $3.90.

IN THE last decade, the struggle for a lucrative market has produced many improvements in beginning texts and this might be expected to include some common agreement on such questions as the order of topics and the level of difficulty of content. A comparison of these two books, however, indicates that the problem of standardization is still a vexed one.

Apparently, to capture the interest of this particular class of reader, the writer should shun didactics and analysis. He should be thematic, according to the practice of good lecturers. Wickens and Meyer may have forecast the shape of texts for replacing lecturers. Learning is used as an introduction and a principle of organization. This design is well realized through transfer and forgetting, motivation, conflict, the emotions, attention, perception, and problem solving. Thereafter, the plan becomes less clear in the chapters on maturation, intelligence, social psychology, normal and abnormal personality, and physiological psychology. The book has many attractive features. The style is conversational and the text replete with examples from ordinary experience. Undue subdividing of content is avoided; sections within chapters are headed by large red type. Instead of tabled data, consolidated experimental results are embodied in clear and simple graphs with the trends shown in red. Apparatus is photographed rather than diagrammed.

One hesitates to carp at any serious effort to write a connected story of psychology. In the absence of data for a completely developmental approach, learning seems well chosen as a coordinating theme, and to enlighten the reader's own motives. The plan may also provide an antidote to reification of complex concepts encountered in personal-social topics. But the intent to keep clear of confusion and to interest the reader has been realized at the cost of oversimplification. Technical terms have been

reduced to the bare minimum, statistical method excluded on the ground that beginners should not be expected to draw conclusions from data, and qualification generally avoided. Space which might well have contained more controversial findings and theory is occupied by the numerous examples from life which form the matrices for the technical points. The general effect is undue compression of the psychological substance, and this, together with the lack of fine breakdown of content, may detract from the book's value for teaching and assessment. There seems to be little virtue in fostering a comfortable belief, later to be unlearned, that the discipline is coherent. Surely the honours student should be led into early contact with complex issues, thence to get on with the job of making his contribution to research or practice. In its present form, the book seems more suitable for the bright layman, or for the non-major who may take topical courses for the general arts degree, than it is for the budding professional.

Karn and Weitz have explicitly designed their text for the terminal non-major. They claim to have stressed "personal adjustment," but it is not forced on the reader. Their style of writing is informal, but the general order of topics is traditional: sensing, perceiving, learning, motivation, reasoning, frustration and conflict, personality, individual differences, and measurement. The inconsistency is only formal. A reading of the book shortly after the other creates the impression that it contains more information, despite its somewhat more restricted coverage. Admittedly, the book has a familiar pattern, but there is more to it than this. The writing is economical, the treatment of the material direct, systematic, and analytic. Illustrative examples are abundant but brief, as though depending on the reader to elaborate. There is less diffidence about technical terms and there is a short but functional account of statistical method. There is practically no tabular material, but the reader feels continually in touch with the research findings. Sales appeal in the form of "window dressing" is not prominant. The illustrations are simple and relatively as numerous as in the other text but they are diagrammatic and graphic. There are sets of questions for discussion after each chapter. Here is a book with a more superficial purpose, but in many ways more factual and didactic than the other, and no less interesting. Do we detect a tendency to reverse educational aims in such terms as coddling the prospective graduate student to keep him in the fold, while giving others the true facts so they will not leave with the wrong impression and do us harm? If this text turns out to be as useful for the non-major as it seems, that by Wickens and Meyer is distinctly too superficial for the future specialist.

A. H. Smith

Queen's University

Delinquent Boys. By Albert K. Cohen. Glencoe, Ill.: Free Press, 1955. Pp. 202. $3.50.

This book presents a sociologist's description of the value systems possessed by a group of delinquent children and a theory concerning the formation and acceptance of these values. Members of mental hygiene teams involved in dealing with juvenile delinquents in courts or in the community will appreciate Dr. Cohen's theme, although it probably represents a concept which they have already experienced and accepted in dealing with delinquent children.

It has been observed and recorded frequently that much juvenile delinquency is an attempt on the part of the individual delinquent to gain status within his peer group by accepting the values of the particular part of the culture under which he has developed. Dr. Cohen attempts to explain the central concept that "stealing is a claim to status in one group and is degrading behaviour in the other." He makes use of very turgid prose and it is the reviewer's opinion that the book would profit greatly by more simplified writing. Although the author frequently reassures the reader that any theme of mono-causativeness in delinquency is untenable, he frequently appears to lose sight of the bio-social-psychological factors involved in understanding the aetiology of such anti-social behaviour disorders.

John D. Atcheson

Toronto Juvenile and Family Court

Psychoanalytic Interpretation in Rorschach Testing. By Roy Schafer. Toronto: Ryerson Press, 1954. Pp. xiv, 446. $9.50.

This book should be on every clinical psychologist's bookshelf: but a solid grounding in Rorschach principles and technique and a general knowledge of psychoanalytic theory and terminology are necessary to appreciate its content. Perhaps the most valuable section of the book for novice and seasoned tester alike lies in the first seventy pages. These pages are given over to an exhaustive and penetrating discussion of the dynamics of the total testing situation. The attitudes and expectations, overt and latent, which both tester and patient bring to the situation are systematically presented; and their influence on the resultant test behaviour and responses, and their interpretation, is described. This section can give every tester insight into the stresses and strains of his role.

Next comes a discussion of the response process itself. It concerns four levels of psychic functioning from regressive to progressive, i.e. dreaming, daydreaming, purposeful visualizing, and normal perceiving; and

presents the nature of and reason for Rorschach responses at all four levels. Major themes in psychoanalytic personality classification are presented and their Rorschach content equivalents are given. These are not offered dogmatically, however, but only as guideposts for which each tester must find conclusive justification before attempting symbolic interpretation.

The last section of the book deals in turn with four common Freudian defences. Test expectations, case studies, and general remarks are made concerning each. Opportunity is taken here to weave into the discussion various points made in earlier sections of the text so that an integrated picture of the psychoanalytic viewpoint in Rorschach interpretation is presented.

MARY W. LAURENCE

Dalhousie University

Identity and Interpersonal Competence, a new direction in Family Research. By NELSON N. FOOTE and LEONARD S. COTTRELL, JR. Chicago: University of Chicago Press (Toronto: Univer. of Toronto Press, 1955). Pp. ix, 305. $5.00.

THIS BOOK makes a significant and timely contribution to research on the family. It is directed to social scientists and to professional workers in organizations serving families. Following a sketch of the trends in family research, it is stated that "the task of future research must be to generalize the conditions under which the person becomes competent to handle the dynamic world he confronts." The basic concept employed is that of "competence in interpersonal relations" which is defined analytically as consisting of health, intelligence, empathy, autonomy, judgment, and creativity. A scheme for the development of hypotheses for experimentation is set forth in which the above six components of competence are considered to be consequent variables, with antecedent conditions being classified under six categories: biological, economic, social-legal, interpersonal, educational, and recreational. An examination of family-serving agencies is made, as a foundation for their participation in research which itself changes the unit under study. The argument then moves on to a plea for a more vigorous participant-experimental approach. A bibliographical appendix lists over a thousand titles on family research in America published from 1945 to 1954. This book represents a contribution that no one interested in the study of the family can afford to miss.

KARL S. BERNHARDT

University of Toronto

Annual Review of Psychology, Vol. 7. Edited by P. R. FARNSWORTH and Q. MCNEMAR. Stanford, Calif.: Annual Reviews, Inc., 1956. Pp. vi, 448. $7.50.

THE UNTIMELY DEATH of Calvin P. Stone, first editor of this *Review*, has in no way affected its standards, and Volume 7, edited by Paul Farnsworth, will be useful to every psychologist and indispensable to the specialist seeking authoritative surveys of other fields than his own. The choice of reviewers is again an excellent one, and almost all chapters display a high level of organization, condensation, and judicious commentary. The taxing assignment of reviewing almost 200 papers on learning is handled by W. K. Estes with easy mastery; his perceptive summaries and witty appraisals are alone worth the price of the book. The chapters on Personality, Social Psychology, Psychotherapy, Counselling, and Assessment are almost equally readable and illuminating. The freedom accorded to individual authors is reassuringly in evidence, as in Hess's criticisms (in Comparative Psychology) of Meyer's treatment of ethology in Volume 6.

There are few changes in content from Volume 6. Individual Differences is dropped for this year, and a chapter on Gerontology replaces that on Problem Solving. Lorge finds little in Gerontology but fact-gathering; Tyler's picture of Educational Psychology is a barren one, doubtless because of the frank inapplicability of current notions of learning to this, our oldest applied field. The promised chapter on psychology in the U.S.S.R. is still in the offing.

The problem of subdividing our discipline is notoriously difficult, and one should not quarrel with the fact that the *Review*'s solution precludes any unified treatment of either motivation or perception. Such a plan, however, demands unusual care in indexing, and it is disturbing to find, under "motivation," no direct references to Estes' valuable section on Drive. It may also be time for the editors to consider a chapter on Communication Theory, scarcely touched on in this volume.

Finally, in so well prepared a collection, there seems no adequate reason why nine out of sixteen bibliographies should fail to include titles, and why four of these should even spurn alphabetical arrangement. The next volume should certainly adopt a uniform style of citation, preferably that of the APA.

J. D. KETCHUM

University of Toronto